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Kepone Mitigation Feasibility Project. Appendix B Remedial Conventional Measures for Capturing, Stabilizing or Removing Kepone in Bailey Bay, Bailey Creek, Gravelly Run, and the James River - Virginia

(U.S.) Army Engineer District, Norfolk, VA

Prepared for

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APPENDIX B

PB 286 086

THE EPA KEPONE MITIGATION FEASIBILITY PROJECT REPORT

REMEDIAL CONVENTIONAL MEASURES

FOR

CAPTURING, STABILIZING OR REMOVING KEPONE IN BAILEY BAY, BAILEY CREEK, GRAVELLY RUN, AND THE JAMES RIVER-VIRGINIA.

U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT

June 1978

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This report is Appendix B of the EPA report "Mitigation Feasibility for the Kepone-contaminated Hopewell/James River Areas". The work reported in this appendix was conducted by the Norfolk District Corps of Engineers for the EPA Kepone Mitigation Feasibility Project. The appendix includes a description of: (1) analysis of world-wide dredging techniques, site surveys, and assessment of the most promising dredging techniques for removal of contaminated sediments from specific sites; (2) engineering studies to contain, stabilize or remove Kepone-contaminated sediments at points of inflow into the James River, together with an assessment of their effectiveness and potential environmental impacts; and (3) evaluation of the engineering requirements for removal of Kepone-contaminated sediments from the James River and assessment of dredge spoils sites.

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FOREWORD

This report has been prepared as one of the inputs to the Environmental Protection Agency's Kepone Mitigation Feasibility Project. The funded participants included: the Corps of Engineers, Norfolk District; the Department of Energy Battelle Pacific Northwest Laboratories; EPA's Gulf Breeze Environmental Research Laboratory; and the Virginia Institute of Marine Science. The separate reports of the participants appear as Appendices to the Kepone Mitigation Feasibility Project Report.

While conclusions and recommendations are included in each participant's report, they are conditional within the scope of each project participant's tasks. Project conclusions and recommendations are the responsibility of EPA and are included in the Kepone Mitigation Feasibility Project Report.

The Corps of Engineers tasks included:

a. Analysis of worldwide sediment removal/dredging techniques and applicability.

b. Engineering studies to contain, stabilize, or remove Kepone contaminated sediments in Bailey Bay, Bailey Creek, and Gravelly Run.

c. Evaluation of environmental impacts of selected engineering alternatives applied to Bailey Bay, Bailey Creek, and Gravelly Run.

d. Evaluation of the engineering requirements for removal of Kepone contaminated sediments from the James River.

APPENDIX B

THE EPA KEPONE MITIGATION FEASIBILITY PROJECT REPORT

REMEDIAL CONVENTIONAL MEASURES FOR CAPTURING,STABILIZING OR REMOVING KEPONE IN BAILEY BAY,BAILEY CREEK,GRAVELLY RUN, AND JAMES RIVER,VIRGINIA

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APPENDIX B

THE EPA KEPONE MITIGATION FEASIBILITY PROJECT REPORT

REMEDIAL CONVENTIONAL MEASURES FOR CAPTURING , STABILIZING OR REMOVING KEPONE IN BAILEY BAY , BAILEY CREEK ,GRAVELLY RUN , AND JAMES RIVER , VIRGINIA

PURPOSE AND AUTHORITY

The report is being submitted in compliance with Interagency Agreement EPA-IAG-D7-01074 between the Environmental Protection Agency and the U.S. Army Corps of Engineers. The agreement, which was signed by the Environmental Protection Agency on 3 March 1977 and the Norfolk District, Corps of Engineers on 29 March 1977, is pursuant to the Economy Act of 1932, as amended (31 U.S.C. 686), the Federal Water Pollution Control Act of 1972 (Public Law 92-500), The Clean Water Act of 1977 (Public Law 95-217), and the River and Harbor Act of 1965, as amended (Public Law 89-299).

The report serves as a technical and engineering document that can be integrated into the overall Environmental Protection Agency's feasibility project report on Kepone.

SCOPE

The preliminary engineering studies presented in this report represent one component of the overall Kepone feasibility study being conducted by the Environmental Protection Agency. The report has been prepared in response to specific Corps tasks as requested by the Environmental Protection Agency. It is divided into a main report and an appendix. The main report is divided into five parts as follows:

Part 1. An investigation of the dredging technology now available on the world market as well as methods to reduce and control the resuspension of secondary pollution.

Part 2. Investigation of alternatives for removing or mitigating the impact of the contaminated sediments in Bailey Bay, Bailey Creek, and Gravelly Run.

Part 3. Dredging analysis of the James River.

Part 4. Conclusions.

Part 5. Recommendations.

PART 1. DREDGING TECHNOLOGY ON THE WORLD MARKET

GENERAL

The Environmental Protection Agency has requested that this office evaluate all potential dredging technology on the world market as well as methods to reduce and control resuspension and concomitant secondary pollution. The results of the study are included in Section A of the appendix.

TYPES OF DREDGES

Dredges in use today can be generally divided into three categories--mechanical, hydraulic, and pneumatic. Mechanical dredges normally lift the dredged material above the water line by means of buckets or scoops of various designs and deposit it in a barge or similar conveyance for transport and disposal. Hydraulic dredges generally move bottom material via a centrifugal pump and pipeline directly toward a disposal area. Pneumatic dredges move bottom material by compressed air. Mechanical dredges can remove bottom material at near inplace density, whereas hydraulic and pneumatic dredges have to add dilution water to form the dredged material slurry.

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DREDGING TECHNOLOGY IN THE UNITED STATES

The following table indicates the types of hydraulic dredges in general use in the United States. They do create some turbidity and resuspension of dredged material.

Table 1. HYDRAULIC DREDGES IN THE UNITED STATES

Type of dredge	Method of operation
Cutterhead	Rotary blades cut into bottom material. Centrifugal pump removes material with dilution water and transports it in a pipeline to disposal area.
Plain Suction	Operates same as cutterhead but without rotary cutter.
Dustpan	Material removed with water jets and picked up with dilution water by a wide but shallow suction inlet, pumped through discharge line, and returned into water adjacent to channel.
Hopper	Dredge equipped with suction pipe, draghead, and hoppers or bins that store hydraulically dredged material. There is no pipeline. Disposal is either at sea or pumped into a disposal site at the pier.
Sidecaster	Material picked up with dilution water and pumped back directly into adjacent waterway, a distance from the channel.

The Mud Cat dredge is comparable to the cutterhead except that, in lieu of a rotating cutter, there is an auger-type horizontal cutterhead. This dislodges the material, and the auger moves it toward the suction pipe. A mud shield surrounds the auger and thereby minimizes mixing of the disturbed bottom sediments with the surrounding water.

The Waterless dredge includes a cutter operating somewhat as a paddle wheel inclosed within a half cylindrical shroud. By forcing the cutterhead into the material, the cutting blades remove the material near the front of the cutterhead with little entrainment of carrier water. The Delta Dredge Model 212 is a small dredge which has two horizontal rotating cutters that provide a relatively shallow cut. They operate at low speed, and it is understood that turbidity levels are low.

Additional hydraulic dredges, described in the appendix, include a cutterhead dredge with small buckets substituted for a cutterhead. Another dredge includes a revolving cylinder swung from a crane, and containing jets that supply water at high pressure so as to loosen bottom sediments to be dredged. A centrifugal pump removes slurry created by the jets. Both dredges have been used mainly in mining operations.

The following table indicates the mechanical dredges in general use in this country. These create considerable turbidity and resuspension of material.

Table 2. MECHANICAL DREDGES IN THE UNITED STATES

Type of dredge	Method of operation	
Dragline	Contains scoop that is lowered into water and slices material to be removed as scoop is drawn toward dredge.	Scoop, shovel, or clamshell is lifted by crane and dredged material is deposited either on a barge or on the bank.
Dipper	Contains shovel that is lowered into water and slices material to be removed as shovel is drawn away from dredge.	
Grab	Contains grab or clamshell bucket. Material is removed by forcing opposing bucket edges into it. Bucket is then closed.	
Endless Chain (bucket ladder)	Includes endless chain of buckets. Material removed by forcing single cutting edge of successive buckets into material. Material deposited in barge or other conveyance.	

Silt curtains are impervious vertical barriers that extend from the water surface down to a specified water depth. They can be used to surround dredging or disposal operations as a means of controlling dispersion of turbid water created by the operation.

In 1976 a report was prepared for the U.S. Army Engineer Waterways Experiment Station which included a number of recommendations for reducing turbidity associated with present dredging procedures and operations. They are summarized in the appendix. The Waterways Experiment Station has a study underway to provide information on the environmental impact of dredging and dredged material disposal operations and to attempt to develop satisfactory, environmentally compatible, and economically feasible dredging and disposal alternatives. This report is scheduled for completion in 1978.

DREDGING TECHNOLOGY IN EUROPE

Dredging technology in Europe is somewhat comparable to that in this country. The bucket dredge, cutterhead, and plain suction dredge are very popular types.

The Pneuma dredge has been developed in Italy. It includes a pneumatic system that is operated by compressed air for dredging sand, gravel, silt, or clay. It includes three steel cylinders, a distributor, and a compressor. Each cylinder is filled with a mixture of water and bottom material to be removed. As soon as it is filled, compressed air acts as a piston and forces the mixture to be expelled from the cylinder to a discharge pipe. According to the manufacturer, it is possible to reach a high solid content in the mixture. He also states that the Pneuma system provides an advantage over traditional dredges in that it does not create secondary pollution.

A series of small dredging units have been developed by IHC Holland. They are designed to dredge under wet or marshy site conditions. They include three dredging techniques--clamshell grab dredging, backhoe dredging, and cutter suction dredging.

Several other types of dredging have been developed. Examples include a pneumatic sand pump dredge that is operated by compressed air. It is used mainly for mining operations. Also an underwater, unmanned bulldozer has been developed which can operate in depths up to 16 feet. It can loosen the material to be dredged, pile it up, and then have it lifted by a grab bucket.

DREDGING TECHNOLOGY IN JAPAN

In recent years, Japan has achieved rapid economic progress. However, the environment surrounding the manufacturing enterprises has deteriorated to a marked extent. Waste water from factories and industrial wastes have produced sludge that has contaminated the sea. Toxic substances present in the sludge have destroyed the environment, and local fisherman have been obliged to change or abandon their occupation. Settling of the sludge also hindered the passage of ships. Thus the social problem became serious.

Accordingly, the Japanese have undoubtedly concentrated on improving the dredging technology for avoiding resuspension of sediments more than any other country in the world.

The following table presents data on the types of dredges that have been developed in Japan. Secondary contamination problems have been reduced materially.

Table 3. DREDGES DEVELOPED IN JAPAN

Type of dredge	Method of operation
Clean Up	Looks like a conventional hydraulic cutterhead except for clean up head installed on ladder. Head is equipped with a moveable wing or shield to overlie bottom sediment, a moveable shutter plate, an auger, a device for collecting gas, and sonar devices to indicate elevation of material before and after dredging.
Anti-Turbidity System for Hopper dredges	Overflow system on hopper dredges is designed to have turbid water (slurry hopper dredges mixture) that is discharged overboard quickly submerged. Discharged slurry settles rapidly to the bottom instead of remaining suspended in the water column.
Oozer	Comparable to Pneuma pump in utilizing water pressure to raise material to be dredged. In addition suction is increased by creating a vacuum in the tank. After material has filled tank, compressed air forces sludge to be discharged. Transports sludge in high density and without causing significant turbidity. Well suited for removal of viscous sediments.
Watertight Grab Bucket	Closed type. Especially designed for dredging without giving rise to secondary pollution when used for dredging settled sludge.

A method developed by a Japanese firm, Takenaka Komuten Co., stabilizes and solidifies polluted sludge in situ with such treatment materials as portland cement combined with various types of admixtures. The resulting sludge, combined with the hardening

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materials increases in strength over a period of time and can be used, for example, in land reclamation. Takenaka procedures include the following methods:

a. Takenaka Sludge Treatment System. This involves the dredging of sludge deposited in water or pollution discharged from factories and sewage treatment plants and mixing it with a solidifying agent prior to disposal.

b. Surface Stabilization System. This involves treatment of sludge in situ with a surface layer stabilizer. The area which can be treated with this procedure is wide. When the thickness of the mud layer is great, only the top portion needs to be solidified to prevent harmful substances from emerging from the top of the mud.

c. Deep Chemical Mixing Method. With this method, soft ground that has been formed by natural decomposition is solidified in situ and transformed into a stable foundation capable of bearing the load of upper structures. The strength of soft ground is increased by mixing a solidifying chemical into the slurry form, feeding it to a Deep Chemical Mixer and then mixing it thoroughly and evenly with the soft ground over the entire depth that is in need of improvement. This system is capable of stabilizing ground below the sea bottom to a considerable depth.

DREDGING TECHNOLOGY IN OTHER COUNTRIES OF THE WORLD

As far as can be ascertained, dredging is generally performed with the major equipment manufactured in the United States, Europe, and Japan.

EXAMPLES OF METHODS UTILIZED TO AVOID RESUSPENSION OF SEDIMENTS

Examples of actual accomplishments are presented. In the case of the Port of Tagonoura, the seriousness of the pollution problem created by the accumulation of toxic sediments was reported throughout Japan. Plans were developed to remove the polluted sediments resulting from paper factory wastes, contamination from food factories, and domestic sewage. The plan included the following:

a. Bottom sediments were removed by a cutterless suction dredge and pumped or barged ashore.

b. A land booster pump moved the slurry (toxic sediments and water) through a pipeline to a dehydration pond. Chemicals were added during the operation to provide protection to workers and the environment during dredging and dehydration.

c. Material removed from the dehydration pond was placed either in a riverbed or on land adjacent to port facilities. Treated water from the dehydration pond flowed back into the river.

In the case of the Duwamish Waterway, an electrical transformer containing PCB's was dumped into a navigation slip in the harbor. An emergency removal operation was first attempted, utilizing small hand held suction dredges to pump the water and contaminated bottom sediments into settling basins. Although some of the PCB's were removed during the operation, sampling of the remaining sediments indicated that large quantities of bottom sediments were contaminated, and an enlarged dredging and disposal operation would be required. The plan developed was to remove the bottom sediments with a Pueuma dredge, pump the material to a shore disposal area, and treat it with chemicals. After treatment, the water effluent was returned to the Duwamish River (Puget Sound).

During a recent trip to Japan, representatives of the Environmental Protection Agency and Corps of Engineers inspected both a large and small Oozer dredge in operation. There was considerable equipment on the head of the Oozer to insure the least amount of secondary pollution as a result of dredging. This included a hood over the suction inlet to recover oil and gas during dredging operations and another cover around the suction inlet to deter contamination of the water surface. The large Oozer was equipped with two television cameras to monitor the turbidity of the water and a sediment detector to accurately measure the thickness of the sediment layer to be removed. The barge carrying the smaller Oozer drew about 2 meters of water. During the operation of the small Oozer, there was no turbidity visible on the surface of the water.

The team inspected the site of an old steel mill wherein a substantial amount of coal ash and other pollutants had been discharged. The material was being dredged, placed in barges, and then towed to a mixing plant containing the soil solidifier. Air contaminants were removed and filtered before being emitted into the atmosphere. After the operation in the mixing plant, the material, in heavy slurry form, was moved to holding bins for 3 days before being truck hauled to a landfill. Excess water was processed in a waste water treatment plant. Every effort was made to avoid secondary pollution. Even contaminated runoff was treated before it was allowed to enter the natural environment.

At another location in Japan, the team investigated an area of 12,000 square meters in which the top 1-1/2 meters had been hardened via the surface layer stabilization system. A square pit was opened down to the bottom of the treated material. Beneath the pit, the untreated sludge was in its natural state, very runny and incapable of supporting structures. Yet the Japanese stated that the surface solidified layer could support light industry.

The group also investigated a Deep Chemical Mixing project in operation in Tokyo Bay. Artificial islands of disposed wastes are now being created in Tokyo Bay by containing waste materials within concrete walls constructed in the bay. At this site, the crew was stabilizing soft clay at the sea bottom with the DCM machine to a depth of 42 meters below mean sea level. The sea was 5 to 10 meters in depth. Solidifying chemicals were mixed in slurry form and fed to the DCM at the site. It mixed the solidifier thoroughly and evenly into the soft ground in situ over the entire depth in need of improvement. This solidified soil is now being used to support some of the walls creating the islands.

DREDGING BAILEY BAY

Testing indicated that the majority of the Kepone contaminant was limited to the top 15 inches of sediment in the bay. Consequently, estimates reflect an attempt to excavate as close to this depth as the capability of the proposed dredging plant allows. Based on the equipment previously described, the following three types of dredges could be considered for removing the contaminated material from Bailey Bay.

- The small Japanese Oozer
- A small dredge such as the American Mud Cat
- The plain suction hydraulic

The Mud Cat requires only about 27 inches of water for floatation. With about 12 inches of water in Bailey Bay at low tide, only the Mud Cat can excavate near the 15-inch depth starting from deep water in the James River. The barge with the small Oozer that was in operation in Japan drew 2 meters, almost 7 feet. It is understood that the

Oozer can dredge in 40 centimeters (approximately 15 inches) of water. It can be placed on a float system to dredge in very shallow water. Also the generator or air compressor can be put on separate units, thereby decreasing the overall depth of the Oozer barge. In the case of the plain suction hydraulic dredge, a 14-inch dredge would be necessary. This requires 5 feet for flotation or the removal of 4 feet of bottom sediment.

Silt curtains, 1,500 feet in diameter, would be placed around each Mud Cat and plain hydraulic suction dredge to help reduce turbidity in the bay. They may not be placed around the Oozer since it does not create significant secondary contamination.

Since it is not possible to dredge to an exact depth, some excess excavation was included in the cost estimates. Also booster pumps in the discharge line were required for the Oozer and Mud Cat. No booster was included for the 14-inch plain suction hydraulic dredge since its equipment can pump the maximum pipeline distance of 8,000 feet to the proposed disposal area.

A disposal area on the east side of Bailey Bay was selected, as previously discussed under the section on disposal areas. This reduces the area to be dredged. Consideration was given toward utilizing three dredges for each system--either three Oozers, or three Mud Cats, or three 14-inch plain hydraulic suction dredges. On this basis, it would take from 3 to 4 months to remove the contaminated bottom sediments from the bay. Since the Oozer equipment is not presently available in the United States the estimates of cost were based on use of the Mud Cat.

One disadvantage of the Mud Cat is the susceptibility of this small dredge to wave action. Even moderate wind and waves could delay dredging. The Oozer would undoubtedly create the least turbidity or resuspension of bottom sediments. Furthermore it requires the least amount of slurry. U.S. patents are now being processed for the Oozer and 6 months or more may be required to mobilize the Oozer from Japan.

DREDGING BAILEY CREEK

Testing indicated that the majority of the Kepone contaminant was limited to the top 15 inches of soil from the mouth of the creek upstream to just above Virginia Route 156 where the 5-foot m.s.l. contour crosses. The trees on the flood plain are substantial in size, some as much as 18 inches or more in diameter. They would have to be felled, then removed by truck and sold either to a paper manufacturing mill or disposed of otherwise. Consideration should be given to chopping the trees with a shredder to facilitate removal to a pulp mill or disposal site. Following removal of the trees, the area would be grubbed; that is, the major tree roots would be removed with a dragline. Chopping of the stumps and roots could also be accomplished. They would be removed by truck to the proposed disposal area. A number of access roads into the creek bottom would be built of sand and gravel to perform these operations.

The following types of equipment could be considered for removing the contaminated material from Bailey Creek.

Cutterhead pipeline dredge equipped with a circular saw in front of the cutterhead to reduce remaining roots to a small size.

- Mud Cat dredge.
- IHC Amphidredges equipped with a Japanese watertight bucket.
- Dragline mechanical dredge.

It is questionable whether the Oozer would operate in a satisfactory manner in a swampy area containing roots and other debris. Its intake would be readily clogged.

The cutterhead pipeline dredge equipped with a rotating circular saw in front of the cutterhead could possibly be utilized in portions of the wetlands, although some of the roots may be difficult to remove. Furthermore, it would be a problem to maneuver the dredge under the bridges. It would probably have to be dismantled and then moved upstream of the Virginia Route 10 bridge crossings. The cutterhead dredge would create much turbidity and resuspension of material.

The Mud Cat could probably operate in the bed of the stream only. It would have difficulty operating in the wetlands due to the clogging of the pump or auger by logs, roots, or other debris. Dredging operations would undoubtedly be slowed by the bars of sediment which protrude above the water level. The auger and intake would have to be raised and the sediment dragged back into the streambed by the mud shield.

The IHC Amphidredge could possibly be equipped with a Japanese watertight bucket. The amphidredge could crawl along on the wetlands. The Japanese closed bucket is especially designed for dredging and generates far less turbidity than the typical open bucket. There is still some resuspension as the bucket impacts the bottom and then is pulled off the bottom. Furthermore, there could be problems if material or debris is caught in the jaws. Unfortunately, such a bucket is not available in the United States at this time.

For the purposes of this estimate, it was assumed that a shore-based dragline would be used to excavate the material from Bailey Creek. The excavation and grubbing of tree roots could be accomplished simultaneously. The dragline plant would utilize a 5-cubic yard bucket and a crane with a boom of 160 feet. If necessary, steel or wooden mats would be placed on the wetlands to ensure stability of the equipment. Due to the inaccuracies of dragline operation, the minimum depth of excavation would have to be about 3 feet. Such a method of operation would generate much turbidity and resuspension of material. Turbidity may be intensified following a heavy rainstorm which, during excavation operations, could wash some of the material into Bailey Bay. About 500 acres would be encompassed within the project area to be cleared and excavated.

PART 2. ENGINEERING ALTERNATIVES FOR BAILEY BAY, BAILEY CREEK AND GRAVELLY RUN

DESCRIPTION OF THE STUDY AREA

PHYSICAL DESCRIPTION

The area under investigation, as shown on plate 1, is about 17 miles southeast of Richmond, Virginia, and lies in the city of Hopewell and Prince George County. Hopewell and Prince George County lie entirely in the coastal plains of Virginia and encompass about 11 and 276 square miles, respectively. The topography is generally hilly with steep streambanks in the vicinity of Bailey Bay, Bailey Creek, and Gravelly Run with elevations ranging from near sea level up to about 130 feet above sea levee. Slopes in the Prince George County portion of the study area can approach 40 to 50 percent in some of the steeper areas. In the city of Hopewell, slopes are generally more gradual and amenable to the development that has occurred. Much of the soil has been formed from rock fragments washed down from the Piedmont area. The area is generally underlain with sand, gravel, and clay strata. Sand and gravel, clay, and greens and marl are plentiful mineral resources in and around the area and are used for commercial purposes. Temperatures in the area average 80° in July and 40° in January with participation averaging approximately 40 inches per year.

For convenience, the study area has been divided into three distinct areas; namely, Bailey Bay, Bailey Creek, and Gravelly Run. Each area is shown on plate 2 and is discussed below.

Bailey Bay. Bailey Bay is a shallow area located adjacent to the James River at the mouth of Bailey Creek. As shown on plate 2, it is situated between Jordan Point to the east and City Point to the west. It is about 2.4 miles in length, 1/2 mile in width, and encompasses about 800 acres. Both Bailey Creek and Gravelly Run discharge into Bailey Bay. The bottom of the bay is shallow with most of the bottom exposed during extreme low tides. A few small vegetated islands do exist in the northern portions of the bay.

Bailey Creek. Bailey Creek, which discharges into Bailey Bay, has a drainage area of about 20 square miles. The creek is 3.2 miles in length from the mouth to Route 156, about 700 feet wide at the mouth, and about 25 feet wide at Route 156. Three bridges cross the creek, one at Route 156 and two at Route 10. Of the 20-square mile drainage area, 14 square miles lie above Route 156. Both the east and west banks of Bailey Creek are heavily wooded.

Gravelly Run. Gravelly Run, which is located about 1,000 feet to the west of Bailey Creek, also discharges into Bailey Bay. It has a drainage area of about 1 square mile and is about 1.4 miles in length from the mouth to the Route 10 crossing. One bridge and a number of pipelines cross the existing creekbed.

HISTORICAL

The first settlement in the Hopewell-Prince George County area occurred in 1613 at City Point where the Appomattox River flows into the James River. It was called Charles City. After the town was destroyed in 1622 by the Indians, it was rebuilt and called Charles City Point. In 1635 Francis Eppes received a grant from King Charles for much of the land at the point, including the town site. His home, Appomattox Manor, which he built on this land, is still owned by descendants and it is on the National Register of Historic Places. In 1702 Prince George County was formed from Charles City County, and the village name was changed to City Point.

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During the Revolutionary War, Benedict Arnold shelled Appomattox Manor in a waterborne assault on the area. The Civil War brought further military action here from June 1864 to April 1865. General Grant set up his headquarters in Appomattox Manor in 1864 and commanded the Union armies in the South and West from this location. President Lincoln and Vice President Johnson also visited City Point during the final stages of the war.

In addition to Appomattox Manor in Hopewell, the following properties in Charles City County are listed on the National Register of Historic Places: Eppes Island, a place of importance, located at the confluence of the James and Appomattox Rivers and Shirley Plantation, located 5 miles north of Hopewell. Other National Register properties in Charles City County, Hopewell, and Prince George County are well beyond the study area.

From an area of about 300 people, Hopewell developed into a boom town, similar to those in the West, after the completion of a dynamite plant in 1913 by the DuPont de Nemours Company. DuPont built its plant on a portion of 1,800 acres of land purchased from the Appomattox Manor estate. With the beginning of World War I, the factory was converted for the production of gun cotton and was making more than 1,000,000 pounds a day until the end of the war. The population of Hopewell was estimated to be approximately 40,000 during this period, with 15,000 to 20,000 people working at the factory. In 1916 Hopewell was incorporated as a city.

With the end of World War I and the closing of the DuPont factory, people left Hopewell as rapidly as they had come. By 1920 the census showed a city population of only 1,320. During the next decade, however, the population began to increase again as new industries moved to the area formerly occupied by DuPont's gun cotton plant.

The first company to locate here after World War I was the Samsocott Company, which began production of cellulose products in 1920. This company was taken over by the Virginia Cellulose Company in 1923 and 3 years later by the Hercules Powder Company. Its principal product was a substance used to make explosives, but it also manufactured film, lacquers, and raw material for rayon, transparent cellulose, and stationery. Today the Hercules Powder Company employs over 1,000 people making plastic materials, synthetic resins, and alkaline and chlorine industrial inorganic chemicals.

One of the largest companies to begin operation in this decade was the Tubize Artificial Silk Company, which bought over 250 acres and built homes for about 500 of the 3,000 employees. This company eventually went out of business as did the Hopewell China Company and the Hopewell Trunk and Bag Company, both of which were established in the 1920's.

The Hummel-Ross Fibre Corporation bought 150 acres for a plant to produce kraft paper and boxboard. The wood from approximately 20 acres of forest was used to produce 45 tons of sulphate liner and 40 tons of wrapping paper daily (Hopewell Chamber of Commerce 1928). In 1949 the Continental Can Company purchased its Hopewell plant from Hummel-Ross Fibre Corporation. Today Continental Can produces liner board and a corrugating medium used in the manufacture of corrugated boxes.

In 1928 Allied Chemical and Dye Corporation spent millions of dollars to set up a nitrate plant through their subsidiary, the Atmospheric Nitrogen Corporation. Later, in 1954, the National Aniline Division of Allied Chemical located a fiber operation along Route 10 next to the nitrogen plant. This plant produced the raw materials for the manufacture of fibers which were sent to a site at Bermuda Hundred in

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Chesterfield County for final processing. In addition to these factories, the General Chemical Division of Allied Chemical built a small plant near Route 10. In 1960 the Aniline Division expanded in order to triple the production of nylon tire cord and start producing nylon yarn. However, most of the expansion occurred at the Chesterfield County yarn plant. Currently, Allied Chemical maintains two plants in Hopewell, the Plastics Division and the Industrial Chemicals Division. Plastics Division, established in 1973 by the merger of the plastics and agriculture plants, produces industrial inorganic chemicals. The Industrial Chemicals Division (I.C.D.) manufactures alum. Together, these two plants employ approximately 800 people.

Firestone is still another industry which found Hopewell an excellent industrial site. Located in the city in 1960, Firestone is a major producer of nylon and polyester yarns. With about 1,500 employees, this company is the largest industrial employer in Hopewell.

SOCIAL BACKGROUND

The populations of both Hopewell and Prince George County have increased since 1950 as seen in the following U.S. Census data:

	1950	1960	1970
Hopewell	10,219	17,895	23,471
Prince George County	19,679	20,270	29,092

However, several annexations have occurred in the past 25 years which affect the above figures. When the 1960 and 1970 counts are adjusted for the annexations occurring through 1972, these figures result:

	1960	1970
Hopewell	18,770	23,471
Prince George County	19,395	24,371

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The most recent estimates indicate that Hopewell has a population of 23,300 and Prince George County has a population of 18,700 as of 1 July 1975 (University of Virginia, 1975). In addition to the annexations, Prince George County's population has fluctuated because of the changes in troop levels at Fort Lee. In 1970 Fort Lee's population was 12,435, a large portion of the county figure of 29,092.

The composition of Hopewell's population by age groups closely parallels the State averages, according to census data, with median age for the city 26.0 and 26.8 for Virginia as a whole. Because of the Fort Lee population, the median age for the county was 22.3, somewhat below the State average. The breakdown by sex also shows similar patterns between Hopewell and the State. Hopewell had slightly more women than men, while the county had 18,753 men and 10,339 women.

Projections for the area's population through the year 2000 show small but steady increases for both Hopewell and Prince George County, as can be seen in the following figures (Virginia Department of Planning and Budgeting):

	1970	1980	1985	1990	1995	2000
Hopewell	23,471	25,000	25,800	26,600	27,200	27,700
Prince George County	29,092	23,000	25,100	27,200	29,300	31,500

The projections of Prince George County estimate considerably more growth for the county than the State projections indicate. In 1980 population is predicted to be 27,300, 31,100 in 1985, and 35,000 in 1990. County personnel predict that the county will grow as a result of more people moving from Petersburg and Hopewell and increased employment opportunities in the area (Prince George County, 1976). However, these projections may be too high when the long-range (20-year) plans of Fort Lee are considered. The master plan of Fort Lee estimates a 4 percent reduction in overall personnel employed and stationed at the base and a much larger decrease in the number of military personnel permanently stationed there (as opposed to TDY personnel) as well as civilians working there.

The housing picture in this area shows somewhat mixed conditions (see table 1). The 1970 home and rent values show Prince George County with fewer houses in the lower price ranges compared to Hopewell, but with levels roughly comparable to the State averages. The rent figures for Hopewell show them to be lower than those for Virginia; those for the county are skewed because of the presence of Fort Lee.

Table 4. VALUE AND CONTRACT RENT OF HOMES (1970)[1]

	Hopewell	Prince George County	Virginia
Value: Specified Owner Occupied			
Less than $ 5,000	2.4%	6.1%	6.7%
$ 5,000 to $ 9,999	21.6	12.1	14.8
$10,000 to $14,999	31.1	18.0	19.7
$15,000 to $19,999	24.6	27.4	18.7
$20,000 to $24,999	10.0	18.8	13.1
$25,000 to $34,999	7.4	13.4	14.4
$35,000 or more	2.9	4.2	12.7
TOTAL	100.0%	100.0%	100.0%
Contract Rent: Specified Renter Occupied			
Less than $ 40	7.5%	6.3%	9.7%
$ 40 to $ 59	14.7	3.2	13.7
$ 60 to $ 79	23.7	4.6	14.8
$ 80 to $ 99	21.6	5.2	11.8
$100 to $149	26.4	31.0	25.3
$150 or more	4.0	4.0	17.1
No cash rent	2.2	45.7	7.6
TOTAL	100.0%	100.0%	100.0%

[1] U.S. Bureau of the Census

In 1970 the housing in the county was slightly more overcrowded and had more overcrowded units than Hopewell's homes, but it was still comparable to the regional average (Petersburg, Colonial Heights, and Hopewell SMSA) for these parameters. One significant difference between the city and county was the percentage of mobile homes in Prince George County--18.4 percent compared to 2.0 percent for Hopewell and 4 percent for the region. The shift from single-family to mobile homes in the county started in the 1960's and may be related to the large increase in housing costs which put the median home value for the county above that for the region as a whole.

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As would be expected, Prince George County's population is much more transient than Hopewell's because of the military presence there. In 1970 only 28 percent of the county residents were living in the same house as they had been 5 years earlier compared to 51 percent in Hopewell and 50 percent Statewide. Correspondingly smaller percentages of county residents in 1970 were living in the same county or state in 1965 than in Hopewell or the State.

Commuter patterns for 1970 show that the in and out commuting to Hopewell tended to balance out, whereas Prince George had almost 2,000 more in-commuters. However, since 1970 the county's importance as an employment center has decreased. Because of Petersburg's annexation in 1972, the county lost the Prince George Industrial Park and the major retail facilities along Route 301.

Manufacturing is the foundation of Hopewell's economy, and it directly provides slightly over 50 percent of the city's jobs. Allied Chemical Corporation, Hercules Powder Company, Firestone Synthetic Fibre Company, and Continental Can Company are the major employers in this area. Additional jobs are found in wholesale and retail trade and in government. By contrast, in Prince George County governmental agencies, primarily Federal, account for two-thirds of the employment as of 1972. This percentage should decrease since civilian employment by the military for the region is expected to fall by 21 percent between 1970 and 1980. On the other hand, regional manufacturing employment is expected to increase 33 percent during the same period (Virginia Department of Planning and Budgeting).

Income levels for both Hopewell and Prince George County are close to State levels as can be seen in the following table:

Table 5. DISTRIBUTION OF FAMILIES BY 1969 INCOME[1]

	Percent of Hopewell total	Percent of Prince George County total	Percent of State total
$ 0 - $ 999	2.2	2.2	2.8
$ 1,000 - $ 3,999	10.6	9.3	13.4
$ 4,000 - $ 7,999	26.7	32.3	26.4
$ 8,000 - $11,999	31.0	28.2	25.3
$12,000 - $14,999	13.1	13.8	12.2
$15,000 - $24,999	14.6	11.8	15.2
$25,000 - $49,999	1.4	2.4	4.0
$50,000 or more	0.4	0.0	0.6
TOTAL	100.0	100.0	100.0
MEDIAN	$9,200	$8,776	$9,049

[1] U.S. Bureau of the Census

LAND-USE PATTERNS AND PLANS

The city of Hopewell occupies an area of approximately 11 square miles or 7,013 acres. According to the Land-Use Plan for Hopewell, Virginia, 56 percent of the land area in 1970 was developed, the majority being in the residential and industrial categories (see table 3).

Compared to other cities of the same size, Hopewell has a far greater percentage of land devoted to industry but less devoted to public and semipublic uses, including roads and streets. The major deficiency is the lack of park and recreation space. Residential acreage per person has been following the national trend, and although substantially larger than similar size cities, Hopewell should maintain a relatively high ratio for the immediate future. Low density and larger lot developments, together with the current tendency to smaller family size, helped to increase this ratio. The city can expect continued extensive use of land for residential purposes as long as these conditions continue.

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Probably the single greatest factor influencing the land-use pattern is the large industrial complex composed of Allied Chemical Company, Firestone, Hercules Powder, and Continental Can Company adjacent to the Poythress Run, the James River, and Route 10. The nature and character of the industry dominates other types of development and has forced development westerly away from the James River. In recent years the greatest amount of population growth has occurred in the western portion of the city toward the boundary of Fort Lee, and it is anticipated that this trend will continue.

Future growth in the Hopewell area is expected to take place primarily south and west of the existing city. Most of this land is suitable for development in terms of its physical characteristics, such as slope. Undeveloped areas adjacent to the James River southeast of the city have been subject to pressure for industrial growth, although much of the present industrial land is open space and can be utilized for necessary expansion in the future.

The section of the city bordering Bailey Creek on the western side is currently zoned for heavy industry to a point just past the old sewage treatment plant and for housing (residential) from that point on (see plate 3). Although much of this area zoned residential is vacant, housing construction is currently taking place between the sewage treatment plant and Route 156.

The creek bank and the adjacent flood plain have been designated a conservation area for future use, and no construction should take place in this area. However, further residential development may occur in areas near the creek, particularly those for which "paper" streets exist. (These streets have been planned but are not yet built.)

Prince George County's total land area is about 276 square miles or 170,640 acres. The dominant characteristic of the land use is the forest and farmland, which take up 94 percent of the total area.

Table 6. EXISTING LAND USE COMPARISON WITH SIMILAR SIZE CITIES

	Hopewell 1/				Similar Size Cities 2/		
Land use category	Acres used	Percent of city area	Percent of developed area	Acres 100/ population	Acres developed	Percent development	Acres 100/ population
Residential	1,762	25.1	44.6	7.80	1,143	41.9	5.12
Commercial	161	2.2	4.0	.71	96	3.5	.43
Industrial	1,266	18.0	32.0	5.61	295	10.8	1.33
Public & semipublic	173	2.4	4.3	.76	492	18.0	2.21
Roads & streets	583	8.3	14.7	2.58	703	25.8	3.15
Total developed area	3,944	56.2	100.0	17.47	2,730	100.0	12.23
Vacant, agriculture & Forest	2,815	40.1					
Water area	254	3.6					
TOTAL	7,013	100.0					

1/ Source: Computer printouts, Hopewell Thoroughfare Plan, 1970. Revised to include annexed area of Prince George County with city of Hopewell.

2/ Source: Land Use in American Cities, Harland Bartholomew, Revised 1969.

Almost three-fourths of the county is in forest land, either for commercial use or as woodlands or farms; 20 percent is farmland other than forest; and the remaining 5 percent is devoted to residential, commercial, industrial, or public use. Much of this forest land exists in large sections of over 400 acres owned by a relatively small number of people. Continental Can Company, Inc., which is the largest single owner, has almost 28,000 acres, or 16 percent of the county. Most of the existing residential development is concentrated near Petersburg and Hopewell and along the main transportation routes. Commercial establishments are generally scattered throughout the county, and industries are found mostly in the section of the county north of Fort Lee. Public recreation acreage, which is limited to land adjacent to public school sites, is considered insufficient for county residents.

The existing zoning for the county has most of the land (87 percent) zoned agricultural. Table 4 shows the breakdown by the seven land-use categories. Much of the land zoned residential is not developed. In fact, if this land was developed at its lowest density of residential use, it would have a population capacity of nearly 67,000 people, a condition not expected until well into the next century.

Table 7. NUMBER OF ACRES, BY ZONING CATEGORY

Category	Acres	Percent Distribution
Residential		
R-1	6,725	3.8
R-2	2,890	1.7
R-3	210	0.1
Subtotal	(9,825)	(5.6)
Business		
B-1	1,550	0.9
Industrial		
M-1	270	0.1
M-2	3,120	1.8
Subtotal	(3,390)	(1.9)
Agricultural		
A-1	152,930	87.2
Federal Land[1]	7,675	4.4
TOTAL ACRES (COUNTY)	175,360	100.0%

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[1] Fort Lee and Petersburg National Battlefield Park

NOTE: These figures are estimated from the Prince George County Zoning Map and are, therefore, approximate.

Current land-use plans aim at concentrating new residential growth in the most populous part of the county near Hopewell and Petersburg and in the existing small communities throughout the rest of the county. The service areas for water and sewerage facilities will be the primary influence over future growth patterns in the more developed part of the county. Public water services will encourage the location of subdivisions and multifamily housing projects, commercial activities, and industrial uses in the more suburban parts of the county. For the rest of the county, retention of agricultural and timber land, especially that which is 20 years old and older, is being emphasized with residential development of low density and large lots being permitted. Both the James and the Appomattox Rivers have the potential to be significant centers for water-oriented recreation activities.

The county land areas adjacent to Bailey Creek are planned primarily for residential development through the year 2000. The creek itself, its tributaries, and their banks have been proposed as critical environmental areas where no construction will take place. Plate 3 shows the projected future land use for most of the county area that lies in the Bailey Creek drainage area. (Most of this area is currently undeveloped forest.) While this area currently has a population of 1,928, the capacity under the proposed plan would be 14,214 people, which would more than cover the projected increases for the next two decades.

Area 1 covers 1,500 acres and includes a housing area and a shopping center. Plans show 25 acres of commercial land use, most of which will be at the intersection of Routes 156 and 646, and 260 acres for residential purposes (see plate 4 and table 5).

Area 2 is mostly undeveloped at present with much of the existing population of 496 centered in the southwest corner. Most of the 3,000 acres are scheduled to remain undeveloped with 515 acres for residential uses, 14 acres for industry, and 5 acres for public use.

The largest section, Area 3, has 4,820 acres and one major residential development. Water and sewer lines, which will encourage residential construction, have been proposed for several sections of this area. In addition to the 800 acres planned for residential zoning, 18 acres will be for commercial structures, and 2 recreation centers will be needed for the increased population (Prince George County, 1976).

Table 8. PROPOSED LAND USES FOR YEAR 2000 IN ACRES

Land Use	Area 1	Area 2	Area 3	Total
Residential	260	515	800	1,575
Multifamily (8 units/acre)	17	50	17	84
4 units/acre	101	200	402	703
2 units/acre	60	170	241	471
1/2 unit/acre	82	95	140	317
Commercial	25	0	18	43
Industrial	0	14	0	14
Public Use	0	5	5	10

ARCHEOLOGICAL RESOURCES

At present, little is known concerning the archeological resources of the project area, although at least five upland archeological sites have been identified by the Virginia Historic Landmarks Commission (see plate 5).

ENVIRONMENTAL

Air Quality. Two air quality parameters are regularly measured in the project area by the Virginia State Air Pollution Control Board; namely, suspended particulates and sulfur dioxides. Recently, testing has indicated that sulfur dioxide does not appear to be a problem. For the year ending March 1977, there were no violations of the National Ambient Air Quality Standards noted in the study area. However, there have been noted violations for suspended particulates. These violations were caused by concentrations of suspended particulate matter exceeding the secondary standards.

Odor is also a problem in the study area. Odor-causing substances are emitted from the several fiber mills in the area. Also the emissions of these substances from Bailey Creek and Bailey Bay "black" water was also noted on several trips to the area. It is expected that the odor problem will abate substantially when the Regional Sewage Treatment Plant begins operation later this year (1977).

Water Quality in the Project Area. The water quality in Bailey Creek and Gravelly Run is governed by the effluent from the sewage treatment plants, industrial outfalls, and cooling water outlets located on these tributaries of the James River. Several outfalls on Bailey Bay also color the water. The volume of waste input to the streams and bay have caused the severe depression of water quality parameters in the area. Dissolved oxygen, pH, BOD, TKN, Nitrate and Orthophosphate parameters vary significantly from the values that would be expected for these types of streams. The Bailey Bay area serves as a mixing zone for the effluents from the Hopewell industrial area; however, the black plume from this area is visible from the air for 5 to 10 miles (8 to 16 kilometers) below Hopewell. The water quality effects of this plume may be evident even after it has completely mixed with water from the James River for many additional miles.

The Regional Sewage Treatment Plant at Hopewell will begin operation this year. It is expected that significant changes in water quality in the project area will be evident. The dissolved oxygen, BOD, and pH problems will be improved, but the exact affect of the plant on other pollutant materials cannot be predicted.

Environmental Setting. The land area included in the study of the alternatives consists of heavily industrialized areas, urban and suburban areas, agricultural areas, upland woods, wooded swamp, and marsh. Data gathered by the U.S. Fish and Wildlife Service personnel during August 1977 indicates that while the upland and marsh areas

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appear normal, exclusive of the odor and color of the water and sediments, there are significant differences between the wooded swamps of Bailey Creek and those of Powell Creek, just downriver. The U.S. Fish and Wildlife Service survey made particular note of the absence of fisheating birds and songbirds in the project area. The cause or causes of this difference was difficult to determine.

When the present water quality of Bailey Creek and Gravelly Run is considered, it is apparent that in addition to this area being environmentally altered, it has affected the chemo-biological regime of the James River as well.

As previously mentioned, the new Regional Sewage Treatment Plant in Hopewell will probably cause a rapid improvement in some water quality parameters in the project area. The treatment will also lessen the readily apparent impact this area has had on the bay and James River systems. Improvement in the water quality of the Bailey Creek and Gravelly Run streams will be buffered by the effects of the polluted sediments in these streambeds.

The return of presently "missing" biota may take many years for the more pollution-intolerant species. Some may never return. The return of pollution-tolerant species to the area may accelerate the uptake of organic and inorganic toxic materials to the food web. This may cause acute and chronic effects on those members of the food web which are sensitive to these toxins. These effects may occur at some distance from the project area. Runoff from the presently existing industrial and urban areas will continue to have a debilitating effect on the Gravelly Run, Bailey Bay, and Bailey Creek areas.

SPECIAL STUDIES

SUBSURFACE INVESTIGATION

Since the Kepone study is only in the conceptual stage of development, the subsurface investigation was limited to 12 borings with standard penetration testing. The locations of these borings, labeled DH-1 through 5 and 7 through 13, are shown on plate 6. All borings were advanced by washing between standard penetration tests. The drilling was accomplished in May 77 by Cunningham Core Drilling and Grouting Company under the supervision of the Norfolk District. Additional subsurface data were obtained from the Virginia State Highway Department and Kenneth Weeks and Associates. This additional information was used as an aid in the interpretation of the subsurface conditions at each of the proposed sites. Individual boring logs are shown in Section E of the appendix to this report. Copies of this additional data are not included with this report. The soil samples obtained during the subsurface exploration were classified according to the "Unified Soil Classification System" using "Burmister's Method of Material Proportions." No rock was encountered within the depths of exploration.

General Geologic Description. The Kepone study area is located in the Coastal Plain Physiographic Province of Southeastern Virginia. Most of the area lies on a series of broad, moderately dissected terraces rising less than 40 feet above sea level. The study area is drained by two tributaries of the James River--Bailey Creek and Gravelly Run. Granite forms the basement rock underlying the sediments of the Coastal Plain. In the Hopewell area, the basement rock is encountered approximately 300 feet below sea level. Sediments of the Potomac Group overlie the granite bedrock and are encountered at about 40 feet below sea level in Hopewell. The Potomac Group sediments are nonmarine Cretaceous Age deposits composed primarily of arkosic sands and gravels with interbedded clay layers. Four Tertiary Age marine formations overlie the Potomac Group along most of the Coastal Plain. Within the study area the upper two formations are absent due to post-Tertiary erosion. The lower two formations, the Nanjemoy and Mattaponi, outcrop along the upper reaches of Bailey Creek and dip eastward under younger Pliestocene deposits. The Nanjemoy and Mattaponi formations are comprised of drab green, gray, and brown quartz-glauconite sands and glauconite-bearing clays. Pliestocene Age fluvial terrace deposits cover most of the study area. These deposits are termed the Columbia Group and are composed of light colored oxidized deposits, mainly sands and gravels with some silts and clays. The Columbia Group in the Hopewell area varies in thickness according to the topography. Generally the thicker sections underlie the higher elevations. Within Bailey Bay and along the tidal influence of Bailey Creek and Gravelly Run, the Columbia Group is overlain by recent organic deposits. These deposits are composed of peat and organic clays and silts. They range in thickness from 50 feet in Bailey Bay to less than 5 feet in lower Gravelly Run and upper Bailey Creek.

Adopted Design Data. Undisturbed samples were not taken during the exploration program because of the general scope and intent of the study. However, strength and consolidation parameters were needed to determine feasible designs for the various alternatives. Some of these parameters were derived from the Windmill Point study which was located on the James River, approximately 5 miles downstream from Bailey Bay. Data from the Windmill Point study were used to evaluate the foundation stability and settlement potential at or near the mouth of Bailey Creek. Strength parameters for the foundation materials at the remaining sites were based on the types of soils encountered and anticipated shear strengths. A complete geological investigation will have to be made before any impoundment is constructed to assure that the impoundment will not allow recharge of any shallow groundwater aquifers by contaminated waters. The shear strengths of the embankment material were based on the types of anticipated borrow material.

Potential Borrow Sources. No subsurface investigations were made to locate or evaluate potential borrow sources for the proposed structures. However, based on past experience with the Windmill Point study and several field reconnaissances of the various sites, it is anticipated that embankment material can be readily obtained from local sources within a 3- to 5-mile radius of each site. Borrow material in the form of sands and gravels can be obtained along the James River across from City Point. Hydraulic dredging would probably be the most economical means of transporting and placing this type of material. Inland borrow sources for clayey sands and sandy clays are available immediately adjacent to the proposed dam across Bailey Creek just upstream of the Route 156 bridge. The final selection of the appropriate source would be determined by economics and subsurface conditions at each site.

SURVEYS

At the initiation of this investigation there were no known detailed topographic data available to facilitate the required preliminary design and associated cost estimates. Cross-sections were obtained on both Bailey Creek and Gravelly Run to aid in the development of the preliminary design features of each alternative including flood routings and channel designs. The location of each cross-section is shown on plate 7 with the detailed section shown in Section D of the appendix.

DISPOSAL AREAS

Several alternatives for eliminating or controlling Kepone contamination involve dredging in Gravelly Run, Bailey Creek, and Bailey Bay. With regard to the consideration of dredging alternatives, it was necessary to locate adequate disposal areas. Realizing the very nature of the material to be dredged, a preview was made of potential

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disposal sites within a reasonable distance of the contaminated areas. Initially, 18 sites, both estuarine and upland, were considered as shown on plate 8. These areas range in size from 10 acres (site 3) up to 606 acres (site 18).

Any disposal area selected would have to be completely sealed and diked to prevent the escape of Kepone. In addition, effluent from the disposal areas would be treated by treatment facilities the design of which is not included in this report. The upland sites would be diked with an impervious material to an appropriate elevation. In addition, the bottom of the upland disposal areas would be sealed with a 2-foot minimum layer of clay to prevent the infiltration of Kepone into the shallow freshwater aquifer. If upland disposal sites are selected, consideration should be given to constructing monitor walls to that for possible contamination of shallow ground water aquifers during operation of the disposal site. With regard to the estuarine sites, containment dikes would be constructed with hydraulic fill. These sites would be sealed by means of an impervious slurry cutoff trench constructed as part of the levee. The slurry trench would be composed of a mixture of sand and bentonite and extend approximately 10 feet below the estuarine's mudline. Unlike the upland sites, no clay cover would be required initially on most of the estuarine sites since the cutoff trench completely seals these areas.

In examining potential estuarine sites, one important consideration was the minimum height of the containment dikes in order to prevent overtopping from flooding in the James River. For the purpose of this study, the 100-Year Flood was selected as the design flood. In this connection, the elevation of the 100-Year Flood on the James River at Hopewell is 8.5 feet m.s.l. Allowing 1.5 feet for freeboard, the minimum levee height was determined to be 10 feet m.s.l.

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In the screening process for selecting appropriate disposal sites, distance from the contaminated areas, topography, accessibility, and potential capacity, as well as environmental and social concerns, were important evaluation considerations. In addition, the selection of one optimum site capable of handling all of the dredged material from Gravelly Run, Bailey Creek, and Bailey Bay was considered the most reasonable and feasible approach since every disposal site would require its own treatment facility.

With regard to upland sites, the only site which is large with respect to potential capacity, flat, easily accessible for truck haul, and at the same time reasonably close to the contaminated areas was site 5 at Fort Lee. However, the very concept of removing contaminated material from an estuarine environment and either pumping or truck hauling it several miles to an uncontaminated upland site presents serious environmental and social problems. In the first place, there is no guarantee that an upland site could be perfectly sealed to prevent the seepage of Kepone into local freshwater aquifers. In addition, a pipeline from Bailey Bay to site 5 at Fort Lee would have to run in the vicinity of the populated portions of Hopewell, and there would always be the risk of having leaks or ruptures occur in the pipeline. Truck hauling the contaminated material through or near Hopewell would also be socially unacceptable. From an economic standpoint, pumping the material in Bailey Bay to site 5 would be expensive. Other upland sites were considered undesirable due to topography, accessibility, capacity, and distance, as well as social and environmental concerns. Consequently, upland sites are believed to be unacceptable for the disposal of Kepone-contaminated sediments and not worthy of further consideration.

After eliminating upland disposal sites from further study, efforts were directed to prime estuarine sites. Utilizing the evaluation criteria previously discussed, selection of the optimum estuarine disposal site appears to be a logical decision. Specifically, site 14 in Bailey Bay would be the most reasonable area since the contaminated material would remain in the same relative environment instead of being transported to one of the less contaminated estuarine sites. Furthermore, the amount of dredging required in Bailey Bay would be reduced by about 500,000 cubic yards and pumping distances for the dredge would be minimized due to the relative proximity of the disposal area. In addition, this site with a design levee height of 10 feet m.s.l. would have the capacity required for all of the contaminated material from Bailey Bay, Gravelly Run, and Bailey Creek. A Mud Cat dredge would be used in Bailey bay, and a dragline dredge would be used in Bailey Creek and Gravelly Run. The reasons for this selection have been discussed in Part 1 under "Dredging Technology". Material dredged from Gravelly Run and Bailey Creek could be easily truck hauled to the site. The main disadvantage of this site would be its impact on the Jordan Point Country Club which overlooks Bailey Bay.

The containment levee for the disposal area in Bailey Bay would be constructed from Jordan Point and extend approximately 8,800 feet to the east side of the mouth of Bailey Creek as shown on plate 9. The disposal area will be equipped with an emergency spillway and a treatment facility for treatment of all effluent from the area. To allow for anticipated settlement, the levee would be over-built initially by 5 feet or to elevation 15 feet m.s.l. A typical cross-section of the levee is shown on plate 10. The levee would be constructed with hydraulic fill and riprap protection on the outside levee slope. The hydraulic fill would be placed in two stages to prevent catastrophic shear failures. The first placement would constitute a working berm with a thickness of 7 feet above the mudline at the center axis of the levee and slopes of 1 on 20. The second stage will include placement of 10 feet of hydraulic fill with 1 on 5 slopes. After the placement of the second stage has been completed, the slopes shall be reworked or shaped to 1 on 3. Filter cloth, bedding material, and riprap shall then be placed on the outside levee slope for protection of the easily erodible hydraulic fill material. A 1-foot layer of gravel placed on the 20-foot wide levee crest is proposed as a working roadbed for equipment. To prevent seepage, a 3-foot wide slurry cutoff trench (bentonite and sand) shall be constructed to a depth of at least 10 feet below the bottom of the hydraulic fill. The slurry trench will be located on the inside levee slope.

Once the disposal area is filled to capacity, it will be sealed on top with a 1-foot minimum layer of clay and seeded. During the actual filling operations, a small staff would be required to operate and maintain the area and to monitor the possible escape of Kepone from inside the levees. This staff could conceivably work in conjunction with that staff required for the treatment facility. Details regarding the onsite staff would have to be worked out in later stages of investigation. In addition, model tests may be desirable prior to any construction to evaluate the effects of the levee on circulation patterns in the James River.

HYDROLOGY

PURPOSE

This section discusses the hydrologic analyses which were accomplished to determine the effects of a plan or series of plans of improvement on runoff quantities from Bailey Creek and Gravelly Run and to determine the size and extent of such improvements needed to eliminate or minimize the amount of Kepone-contaminated runoff entering the James River.

DESCRIPTION OF STUDY AREA

Hopewell is located in the northern part of Prince George County in the west central part of the Coastal Plain, as shown on plate 1. The city of Hopewell is situated at the confluence of the Appomattox River and the James River, while Bailey Creek forms the southeastern boundary of the city limits and empties into the James. Major tributaries that enter Bailey Creek are Southerly Run, Manchester Run, and Cattail Creek. Gravelly Run lies entirely within the Hopewell city limits and empties directly into the James River. The topography in the vicinity of Hopewell is generally level with steep streambanks in the vicinity of Bailey Bay, Bailey Creek, and Gravelly Run, with elevations ranging from near sea level up to about 130 feet above sea level. Plate 11 delineates the drainage areas studied in the Bailey Creek and Gravelly Run watersheds.

CLIMATOLOGICAL DATA

The climate of Hopewell is characterized by mild winters and warm and humid summers. The large open bodies of water nearby and to the east, which are slow in reacting to atmospheric changes, contribute to the humid summers and mild winters. The mean annual temperatures at Hopewell are slightly higher than the average of other stations in this region due to the proximity of the James River which is quite wide at this location.

The National Weather Service supervises the collection of climatological data by cooperative observers from substations at Fort Lee and Hopewell. Data on monthly variations in precipitation and temperature for the two substations are shown in table 9.

TABLE 9. CLIMATOLOGICAL DATA, HOPEWELL [1] AND FORT LEE [2] VIRGINIA

Month	Temperature, °F		Precipitation, inches	
	Hopewell	Fort Lee	Hopewell	Fort Lee
January	40.3	38.4	2.88	3.08
February	42.3	40.1	3.08	3.24
March	49.7	46.9	3.13	3.34
April	60.2	57.3	3.03	3.17
May	68.5	65.9	3.72	3.54
June	75.8	73.5	3.97	4.53
July	79.1	77.2	5.34	5.71
August	77.7	75.9	4.84	4.93
September	71.7	69.1	3.65	3.58
October	61.3	59.1	2.92	3.32
November	51.4	49.0	2.96	3.13
December	41.7	39.7	3.12	3.16
ANNUAL	59.9	57.6	42.64	44.73

[1] Based on 1940 - 1969 averages.
[2] Based on 1946 - 1970 averages.

STORM CHARACTERISTICS

Precipitation in the Hopewell area is well distributed throughout the year with the maximum in July and the minimum in January, but a relatively dry period extends from September through April. Intense summer thunderstorms are perhaps the most likely source of heavy rainfall within the Bailey Creek and Gravelly Run watersheds. Other sources of storms include hurricanes or remnants of same during the summer and fall months. All are capable of producing unusually high peak discharges on these streams.

RAINFALL FREQUENCY

Shown in table 10 are the rainfall of various durations and frequencies appropriate for the Hopewell area, as indicated in "Technical Paper No. 40, Rainfall Frequency Atlas of the United States," published by the U.S. Weather Bureau. The greatest daily rainfall at the nonrecording Hopewell substation occurred 15 August 1940 when 5.56 inches fell, while the nonrecording Fort Lee substation recorded its largest daily rainfall of 6.18 inches on 12 August 1955.

TABLE 10. RAINFALL FREQUENCY

Rainfall duration in hours	Rainfall in inches and frequency in years				
	2	10	25	50	100
0.5	1.45	2.10	2.50	2.83	3.00
1.0	1.75	2.66	3.20	3.52	4.00
2.0	2.05	3.13	3.70	4.10	4.70
3.0	2.28	3.52	4.05	4.53	5.12
6.0	2.78	4.08	4.80	5.55	6.00
12.0	3.29	5.00	5.70	6.23	7.00
24.0	3.45	6.00	6.35	7.00	8.00

STREAMFLOW

Currently there are no gaging stations located in either Gravelly Run or Bailey Creek watershed. As there are no discharge records available, discharges were computed using the procedure described in Snyder's "Synthetic Flood Frequency Method," Journal of Hydraulics Division, Proceedings of American Society of Civil Engineers (ASCE), dated October 1958. The Standard Project Flood (SPF) determinations were made using the simplified procedure in EM 1110-2-1411 (formerly Civil Engineer Bulletin No. 52-8), entitled "Standard Project Flood Determinations." For all discharge computations, an initial loss of 0.80 inch and infiltration loss of 0.05 inch per hour were used. These values were based on experience of the Norfolk District in related studies and were considered to be reasonably conservative and applicable to the watersheds in the vicinity of Hopewell. A summary of the unit hydrographs for the drainage areas studied is included in table 11.

Table 11. SUMMARY OF UNIT HYDROGRAPHS IN C.F.S.

	Bailey Creek Watershed						
Time, hours	Above Route 156 13.56 sq. mi.	Above confluence with Cattail Creek 14.35 sq. mi.	Below confluence with Cattail Creek 17.25 sq. mi.	Cattail Creek 2.90 sq. mi.	Local with Cattail Creek 6.99 sq. mi.	Local 4.09 sq. mi.	At conflue with Jame River 20.55 sq.
0.50	104	39	46	45	11	6	13
1.00	375	142	171	162	40	23	50
1.50	732	284	341	308	80	47	101
2.00	1,115	443	533	446	126	74	162
2.50	1,482	611	735	530	176	103	228
3.00	1,753	783	941	537	227	133	298
3.50	1,878	954	1,147	460	280	164	371
4.00	1,864	1,103	1,325	342	333	195	446
4.50	1,672	1,210	1,454	249	384	225	522
5.00	1,363	1,275	1,533	181	429	251	599
5.50	1,078	1,301	1,564	131	462	270	676
6.00	853	1,287	1,547	95	486	284	753
6.50	674	1,227	1,475	69	499	292	826
7.00	533	1,103	1,326	50	503	294	888
7.50	422	951	1,143	37	498	291	939
8.00	333	817	982	27	481	282	980
8.50	264	702	844	19	449	263	1,010
9.00	209	603	725	14	403	236	1,030
9.50	165	518	623	10	357	209	1,041
10.00	130	445	535	7	317	185	1,041
10.50	103	382	460	5	281	164	1,032
11.00	82	329	395		249	146	1,012
11.50	64	282	339		221	129	980
12.00	51	243	292		196	115	928
12.50	40	208	250		174	102	859
13.00	32	179	215		154	90	789
13.50	25	154	185		136	80	725
14.00	20	132	159		121	71	666
14.50	16	114	136		107	63	612
15.00		98	117		95	56	563
15.50		84	101		84	49	517
16.00		72	87		75	44	475
16.50		62	74		66	39	436
17.00		53	64		59	34	401
17.50		46	55		52	30	368
18.00		39	47		46	27	339
18.50		34	41		41	24	311
19.00		29	35		36	21	286
19.50		25	30		32	19	263
20.00		21	26		29	17	241
20.50		18	22		25	15	222
21.00		16	19		22	13	204
21.50		14	16		20	12	187
22.00		12	14		18	10	172
22.50					16	9	158
23.00					14	8	145
23.50					12	7	133
24.00					11	6	123
24.50					10	6	113
25.00					9	5	103
25.50					8	4	95
26.00					7	4	87
26.50					6	3	80
27.00					5	3	74
27.50						3	68
28.00						2	62
28.50							57
29.00							53
29.50							48
30.00							44

Table 11. SUMMARY OF UNIT HYDROGRAPHS IN C.F.S.

	Bailey Creek Watershed						Gravelly Run Watershed
e 156 . mi.	Above confluence with Cattail Creek 14.35 sq. mi.	Below confluence with Cattail Creek 17.25 sq. mi.	Cattail Creek 2.90 sq. mi.	Local with Cattail Creek 6.99 sq. mi.	Local 4.09 sq. mi.	At confluence with James River 20.55 sq. mi.	At confluence with James River 1.00 sq. mi.
04	39	46	45	11	6	13	22
75	142	171	162	40	23	50	76
32	284	341	308	80	47	101	143
15	443	533	446	126	74	162	195
82	611	735	530	176	103	228	214
53	783	941	537	227	133	298	189
78	954	1,147	460	280	164	371	139
64	1,103	1,325	342	333	195	446	96
72	1,210	1,454	249	384	225	522	67
63	1,275	1,533	181	429	251	599	46
78	1,301	1,564	131	462	270	676	32
33	1,287	1,547	95	486	284	753	22
74	1,227	1,475	69	499	292	826	15
33	1,103	1,326	50	503	294	888	11
22	951	1,143	37	498	291	939	7
33	817	982	27	481	282	980	5
54	702	844	19	449	263	1,010	4
09	603	725	14	403	236	1,030	2
65	518	623	10	357	209	1,041	
30	445	535	7	317	185	1,041	
03	382	460	5	281	164	1,032	
82	329	395		249	146	1,012	
64	282	339		221	129	980	
51	243	292		196	115	928	
40	208	250		174	102	859	
32	179	215		154	90	789	
25	154	185		136	80	725	
20	132	159		121	71	666	
16	114	136		107	63	612	
	98	117		95	56	563	
	84	101		84	49	517	
	72	87		75	44	475	
	62	74		66	39	436	
	53	64		59	34	401	
	46	55		52	30	368	
	39	47		46	27	339	
	34	41		41	24	311	
	29	35		36	21	286	
	25	30		32	19	263	
	21	26		29	17	241	
	18	22		25	15	222	
	16	19		22	13	204	
	14	16		20	12	187	
	12	14		18	10	172	
				16	9	158	
				14	8	145	
				12	7	133	
				11	6	123	
				10	6	113	
				9	5	103	
				8	4	95	
				7	4	87	
				6	3	80	
				5	3	74	
					3	68	
					2	62	
						57	
						53	
						48	
						44	

B

The peak discharges, shown in table 12, demonstrate a significantly large decrease in discharges at the mouth of Bailey Creek compared to those computed at Route 156. This phenomena results from the large amount of flow taken up by storage in the floodway along this relatively flat reach between Route 156 and the mouth, a distance of about 3.5 miles. The hydrographs computed for the mouth of Bailey Creek when compared to those at Route 156 have a larger total volume due to the additional contributing drainage area and are flatter (smaller peak) and more drawn out in time due to the effect of storage.

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Table 12. PROBABLE PEAK DISCHARGES AND ESTIMATED FREQUENCIES

	Bailey Creek Watershed							Gravelly Run Watershed
Item	Above Route 156	Above confluence with Cattail Creek	Below confluence with Cattail Creek	Cattail Creek	Local with Cattail Creek	Local	At confluence with James River	At confluence with James River
Drainage area, sq. mi.	13.56	14.35	17.25	2.90	6.99	4.09	20.55	1.00
Time of concentration, hours	4.27	6.59	6.59	3.16	8.31	8.31	11.81	2.76
Discharge in c.f.s. with frequency of:								
2 years	3,740	-	-	1,030	-	-	-	400
10 years	6,970	4,800	5,770	1,740	-	-	4,170	680
25 years	7,540	-	-	2,040	-	-	-	790
50 years	9,250	6,370	7,650	2,310	-	-	5,430	890
100 years	9,660	7,150	8,590	2,600	2,860	1,670	6,170	1,010
Standard Project Flood (SPF)	14,240	11,480	13,800	3,570	4,780	2,820	10,600	1,300

The peak of the 2 percent flood (one chance in 50 of being exceeded in a given year on the average) at the mouth of Bailey Creek is about 5,430 cubic feet per second (c.f.s.) under existing conditions or 264 c.f.s. per square mile. A comparison of this discharge with the discharges of other 2 percent floods determined for natural drainage basins of approximately the same drainage area is contained in table 13.

Table 13. COMPARISON OF 2 PERCENT FLOODS

Location	Drainage area, sq. mi.	Peak flow in c.f.s./sq. mi.
Looney Creek near Buchanan	29.6	314
Kerr Creek near Lexington	34.0	391
Bailey Creek at Hopewell	20.5	264
Virginia Beach Canal No. 2	37.0	216
Catawba Creek near Catawba	34.0	200
Fine Creek at Fine Creek Mills	23.0	152
Piney River near Piney River	48.0	105
Falling Creek near Chesterfield	32.9	88

TREATMENT CAPABILITIES

The size of treatment facilities analyzed was based on a time frame considered reasonable to treat and empty the ponding areas of the Kepone-contaminated runoff for various design storms. Three design capacities were selected and included a 50 million gallon per day (M.G.D.), a 100 M.G.D., and a 150 M.G.D. facility. The three sizes of treatment facilities selected provide a range of alternatives to select the required facility if treatment is recommended as part of the plan of improvement. Alternatives included treating all of the Bailey Creek runoff, the runoff of Bailey Creek between Route 156 and the mouth, the runoff from Gravelly Run, and combinations thereof. A summary of the different alternatives and combinations is contained in table 14.

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Table 14. TREATMENT DURATIONS

Location[1/]	D.A. in sq.in.	Ten Percent Flood			Two Percent Flood			One Percent Flood			Standard Project Flood		
		50 M.G.D.	100 M.G.D.	150 M.G.D.	50 M.G.D.	100 M.G.D.	150 M.G.D.	50 M.G.D.	100 M.G.D.	150 M.G.D.	50 M.G.D.	100 M.G.D.	150 M.G.D.
Bailey	6.99	11 days 20 hrs	5 days 15 hrs	3 days 17 hrs	14 days 16 hrs	7 days 0 hrs	4 days 14 hrs	17 days 3 hrs	8 days 4 hrs	5 days 9 hrs	35 days 18 hrs	17 days 1 hr	11 days 4 hrs
Bailey & Manchester	20.55	42 days 14 hrs	18 days 3 hrs	11 days 12 hrs	52 days 21 hrs	22 days 12 hrs	14 days 7 hrs	61 days 18 hrs	26 days 7 hrs	16 days 17 hrs	128 days 19 hrs	54 days 20 hrs	34 days 20 hrs
Bailey & Gravelly	7.99	13 days 16 hrs	6 days 11 hrs	4 days 5 hrs	16 days 23 hrs	8 days 0 hrs	5 days 6 hrs	19 days 20 hrs	9 days 9 hrs	6 days 3 hrs	41 days 11 hrs	19 days 14 hrs	12 days 20 hrs
Bailey, Manchester, & Gravelly	21.55	45 days 11 hrs	19 days 4 hrs	12 days 3 hrs	56 days 8 hrs	23 days 18 hrs	15 days 1 hr	65 days 9 hrs	27 days 19 hrs	17 days 14 hrs	136 days 17 hrs	57 days 15 hrs	36 days 12 hrs
Gravelly	1.00	1 day 13 hrs	0 days 18 hrs	0 days 12 hrs	1 day 22 hrs	0 days 23 hrs	0 days 15 hrs	2 days 6 hrs	1 day 3 hrs	0 days 18 hrs	4 days 17 hrs	2 days 8 hrs	1 day 13 hrs

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1/ Location designates areas being treated.

TIDAL CHARACTERISTICS

The mean tide level of the James River at Hopewell is 1.2 feet with a mean tidal range of 2.5 feet. Tidal elevations which can be expected in the study area can be related to the frequency of tidal flooding in Norfolk Harbor which was developed from the tidal records at Hampton Roads (Sewells Point). The frequency of tidal flooding for the Hopewell area is summarized in the following table.

Table 15. TIDAL STAGE-FREQUENCY FOR HOPEWELL AND VICINITY

Elevation in feet m.s.l	Frequency in percent chance, per year
10.5	0.100
10.0	0.180
9.5	0.330
9.0	0.600
8.5	1.000
8.0	1.800
7.5	3.100
7.0	5.400
6.5	9.000
6.0	15.000
5.5	25.500
5.0	42.000
4.5	75.000
4.4	100.000

ALTERNATIVES

Three different flood volumes (10 percent, 2 percent, and 1 percent floods) were analyzed for storage and treatment in several of the alternatives. Studies showed that the 2 percent and 10 percent flood volumes were within 15 percent and 30 percent of the 1 percent flood volumes, respectively, and the ponding elevations were generally within several feet of the 1 percent flood. The smaller discharges associated with these more frequent storms generally have smaller velocities which are not expected to discharge as much Kepone sediment

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into the James River as the larger discharges. For these reasons, the structures presented herein are only those which are capable of containing the entire 1 percent flood.

One particularly important aspect of each of the structures is that they are capable of withstanding larger floods without failing. The elevation of the top of the structure, together with an adequately sized emergency spillway, insures the integrity of these alternatives even during very rare events. Routing operations were performed with the ponding area filled to one-half the volume of the 1 percent flood and a SPF inflow. The operations illustrate the ability of these structures to withstand larger floods without failing. Other pertinent data are summarized in the following table:

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Table 16. F

Alternative	Elevation of Dam in ft. m.s.l.	Elevation of Spillway Crest in ft. m.s.l.	Length of Spillway Crest in feet	Type of Outlet Works	Size of Outlet Works	Capacities in Acre-Feet			
						Ten Percent Flood	Two Percent Flood	One Percent Flood	S
Alternative 1	18.4	13.1	100	None	None	237	293	343	
Alternative 2A	13.4	8.5	100	Pressure	325 c.f.s.	237	293	343	
Alternative 7	25.0	15.9	100	None	None	4,850	6,015	7,030	
Alternative 7A	25.8	16.9	100	None	None	4,850 3/	6,015 3/	7,030 3/	
Alternative 7B	18.4	8.5	100	None	None	1,650	2,050	2,390	
Alternative 7C	19.8	10.2	100	None	None	1,650 3/	2,050 3/	2,390 3/	
Alternative 7D	25.4	15.9	100	None	None	4,850 2/	6,015 2/	7,030 2/	
Alternative 7E	26.5	16.9	100	None	None	4,850 1/	6,015 1/	7,030 1/	
Alternative 7F	19.0	8.5	100	None	None	1,650 2/	2,050 2/	2,390 2/	
Alternative 7G	20.1	10.2	100	None	None	1,650 1/	2,050 1/	2,390 1/	
Alternative 12	45.0	37.0	200	Gravity	2-10' Corrugated Steel	3,200	3,965	4,640	
Alternative 12A	46.0	37.0	200	Pressure	2-325 c.f.s.	3,200	3,965	4,640	

1/ Only inflow volume from Bailey Creek is shown. Diversion from Gravelly Run and volume of dredge material is not included in the computations.

2/ Only inflow volume from Bailey Creek is shown. Diversion from Gravelly Run is not included in this value but was include

3/ Only inflow volume from Bailey Creek is shown. Volume of dredge material is not included in this value but was included

A

Table 16. PERTINENT DATA OF DAM ALTERNATIVES

in Acre-Feet		One Percent Ponding Elevation in ft. m.s.l.	Standard Project Ponding Elevation in ft. m.s.l.	Guide Taking Elevation in ft. m.s.l.	Pool Acreage			Bridge Relocation or Modification
One Percent Flood	Standard Project Flood				One Percent	Standard Project	Guide Taking	
343	716	13.1	15.4	21.4	50	55	72	None
343	716	7.4	10.4	16.4	33	43	57	None
7,030	14,665	15.9	22.1	28.0	740	885	1,060	1
7,030 3/	14,665 3/	16.9	22.8	28.8	760	900	1,085	2
2,390	4,990	7.9	15.4	21.4	515	665	760	None
2,390 3/	4,990 3/	10.2	16.8	22.8	570	685	780	None
7,030 2/	14,665 2/	15.9	22.4	28.4	740	890	1,070	1
7,030 1/	14,665 1/	16.9	23.5	29.5	760	920	1,110	2
2,390 2/	4,990 2/	7.9	16.0	22.0	515	670	765	None
2,390 1/	4,990 1/	10.2	17.1	23.1	570	690	790	None
4,640	9,675	35.5	42.0	48.0	237	320	405	None
4,640	9,675	36.7	43.1	49.0	280	335	420	None

l is not included in this value but was included

e but was included in the computations.

but was included in the computations.

Project Elevation m.s.l.	Guide Taking Elevation in ft. m.s.l.	Pool Acreage			Bridge Relocation or Modification	Home Relocation	Remarks
		One Percent	Standard Project	Guide Taking			
.4	21.4	50	55	72	None	None	
.4	16.4	33	43	57	None	None	Elevation of spillway is controlled by the one percent tidal frequency. Diversion to Bailey Creek.
.1	28.0	740	885	1,060	1	7	Entire Bailey Creek watershed contributing. Modify Route 10 EBL Bridge.
.8	28.8	760	900	1,085	2	7	Entire Bailey Creek watershed contributing. Dredge fill included. Modify both Route 10 Bridges.
.4	21.4	515	665	760	None	7	Bailey Creek between Route 156 and mouth contributing. Elevation of spillway is controlled by the one percent tidal frequency.
.8	22.8	570	685	780	None	7	Bailey Creek between Route 156 and mouth contributing. Dredge fill included.
.4	28.4	740	890	1,070	1	7	Entire Bailey Creek watershed contributing. Diversion from Gravelly Run. Modify Route 10 EBL Bridge.
.5	29.5	760	920	1,110	2	7	Entire Bailey Creek watershed contributing. Diversion from Gravelly Run. Dredge fill included. Modify both Route 10 Bridges.
.0	22.0	515	670	765	None	7	Bailey Creek between Route 156 and mouth contributing. Diversion from Gravelly Run.
1	23.1	570	690	790	None	7	Bailey Creek between Route 156 and mouth contributing. Diversion from Gravelly Run. Dredge fill included.
0	48.0	237	320	405	None	25	Diversion to James River.
1	49.0	280	335	420	None	25	Diversion to Chappel Creek.

c

SUMMARY

The lack of streamflow and high water data has not made this particular hydrologic analysis an easy task. The area is unique such that conclusions and engineering judgments were drawn only after considerable effort had been made within the available time frame. The analysis is considered to be conservative and adequate with regard to the serious problem that we are charged with addressing.

FORMULATING A PLAN

In formulating a plan it was necessary to identify all the realistic alternatives available to solve the problem and to screen these to select the one best responding to the problem. The selected plan should not only accomplish the objective but must also make a positive contribution to the natural environment of Hopewell and the surrounding area. In screening alternatives, consideration of pertinent costs and environmental impacts were an important part of the screening process.

EVALUATION CRITERIA

Evaluation of the plans of improvement considered in this study is based on technical and economic criteria and on intangible considerations, including possible beneficial and detrimental effects on the area's environment and its social well-being. Such criteria requires that the selected plan be engineeringly feasible and environmentally and socially acceptable.

TECHNICAL CRITERIA

The following criteria were used in developing the plan or plans to be recommended for further consideration.

a. Plans investigated will remove, contain, or stabilize sediments in Bailey Bay, Bailey Creek, and/or Gravelly Run.

b. Any alternative considering dredging will seek to keep resuspended solids to a minimum.

c. Any alternative considering modifying or changing existing drainage networks will be designed to accommodate a 100-year discharge without any major affect on flood stages.

d. Any alternative considering dams will be designed to store the 100-Year Flood and will also pass the Standard Project Flood discharge.

e. The levees for estuarine disposal will be designed to prohibit overtopping by the 100-Year Flood.

ECONOMIC CRITERIA

In order to determine the economic advantage of one plan over another each plan must be evaluated on a comparable basis. The following economic criteria have been adopted for the purpose of this study.

a. Each plan is assumed to have an economic life of 100 years resulting in a 100-year amortization period.

b. Annual charges will be computed at an interest rate of 6-5/8 percent.

c. Interest during construction was not included.

d. Annual charges also include maintenance, operation, and major replacement.

e. All cost estimates are as of August 1977 prices.

ENVIRONMENTAL CRITERIA

The following intangibles were considered in formulating the plans to be recommended for further consideration.

a. Public health, safety, and social well-being, including possible loss of life.

b. Incorporation of pleasing aesthetic and other desirable environmental features into the selected plan.

c. Avoidance, where possible, of detrimental environmental effects and inclusion of mitigating features, if possible, for such effects found to be unavoidable.

ALTERNATIVE STUDIES

The following paragraphs discuss the various alternatives studied for the control of Kepone in Bailey Bay, Bailey Creek, and Gravelly Run. The alternatives described are those presented to EPA on 2 May 1977. Alternatives for each individual area, where appropriate, will be discussed first, even though a complete solution may not be presented. Combination of alternatives will then be presented to provide total stabilization or removal of polluted sediments for the three areas under consideration. This part of the report will discuss only the physical description and engineering and design considerations. In addition, first costs and annual costs will be summarized. Detailed cost estimates are included in Section C of the appendix. The environmental assessment will be presented (separately) in a subsequent section of this report. The various alternatives and combinations of alternatives examined are conveniently tabulated in table 24.

ALTERNATIVE 1

General. One alternative for preventing the escape of Kepone from Gravelly Run would consist of constructing a dam to elevation 18.4 feet m.s.l. near its mouth and treating all runoff from the watershed. This alternative would be constructed with an emergency spillway in conjunction with a required treatment facility.

Site Description. The site of the proposed dam would be located approximately 200 feet downstream of the Continental Can bridge as shown on plate 12. A majority of the site is covered by marsh grass and small bushes. Elevations within this area range from -2 feet to +2 m.s.l. The flood plain is approximately 600 feet wide at this point. The right abutment is heavily wooded with elevations rising from +2 feet m.s.l. in the flood plain to +30 feet m.s.l. The left abutment is honeycombed by a series of industrial waste ponds which range in depth from 5 feet to 8 feet. Topographic surveys would be needed in this area to define the limits and actual depths of these ponds.

Subsurface Conditions. No borings were drilled in the vicinity of the proposed dam. However, based on field observations of open excavations within the area and boring logs from the new Hopewell Sewage Treatment Plant, a soil profile was developed for the proposed site. It is anticipated that approximately 4 feet of soft organics and loose, fine sands overlie the flood plain. Underlying this upper cover are clayey sands and silty sands to a depth of at least 20 feet. The right abutment consists of fine to medium sands (SC-SM) with varying percentages of fines. The soil conditions in the left abutment are similar to the right abutment except where the upper 5 to 8 feet of material has been excavated to construct levees for the industrial waste ponds. These areas would require filling prior to construction of the dam.

Recommended Design. The purpose of the dam would be to store all runoff on the Gravelly Run watershed up to and including the 100-Year Flood. The runoff would pass through a treatment facility for treatment and be discharged into the James River. Runoff in excess of the 100-Year Flood would be discharged directly into the James River without any treatment. The required capacity of the treatment facility would vary, depending upon the selected retention period. For example, if water was stored for 1-1/2 days, a 50 M.G.D. facility would be needed; whereas, if the water was stored for 1/2 day, a 150 M.G.D. plant would be required.

This alternative would require about 72 acres of land and the dam would provide 443 acre-feet of storage. In this regard, no bridges or other permanent structures would be affected.

It is recommended that the proposed dam be constructed from controlled earth fill by conventional means. The dam would have a length of approximately 700 feet. It would have a top width of 5 feet with side slopes of 1 on 3 on the upstream side and 1 on 2.5 on the downstream side. The height of the dam would be about 23 feet, with a top elevation of 18.4 feet m.s.l. which includes 3 feet of freeboard. The upstream side of the dam would be protected by riprap to the top and would be protected to elevation 8.5 feet m.s.l. on the downstream side. The 8.5 feet m.s.l. is the elevation of the 100-Year Flood in the James River.

Prior to placement of the earth fill, approximately 3 feet of material would be removed and replaced with properly compacted fill. In addition to treating the foundation directly under the dam, a slurry cutoff trench, approximately 4 feet wide and 20 feet deep, would be placed in the left abutment to form an impervious cutoff. The cutoff would be carried a distance of approximately 300 feet into the left abutment. Waste ponds within the path of the cutoff would be backfilled to the existing grade. After the cutoff had been placed, the earth dam would be constructed to the design grade. A typical section of the proposed dam is shown on plate 13.

In addition to the dam, an emergency spillway would be constructed. This spillway is designed to accommodate floods up to and including the Standard Project Flood even though the ponding area may be filled to one-half the volume of the 1 percent flood (100-Year Flood) at the beginnning of the SPF. The spillway would have a top elevation of 13.1 feet m.s.l. and would be located in the right abutment on undisturbed soil. The spillway would be 100 feet wide and will have 1 vertical to 2 horizontal side slopes. A 1-foot concrete liner would be required to prevent erosion. Energy dissipators are not considered necessary.

The following table summarizes the pertinent design data associated with this alternative.

Table 17. PERTINENT DESIGN DATA FOR ALTERNATIVE 1

DAM STRUCTURE (100 Year Flood)		
Elevation, ft. m.s.l.		18.4
Length, ft.		700.0
Height, ft.		23.0
Top width, ft.		5.0
Area of watershed, sq. mi.		1.0
Spillway		
Length, ft.		100.0
Elevation, ft. m.s.l.		13.1
Storage, acre ft.		443.0
Land Required, acres		72.0
Required capacity of treatment facility		
1-1/2 days	50 M.G.D.	
3/4 day	100 M.G.D.	
1/2 day	150 M.G.D.	

Potential Construction Problems. The major construction problem would result from the treatment of the left abutment. The existing waste ponds would require draining and backfilling prior to placement of the cutoff. Additional subsurface investigations and topographic surveys would more adequately define the existing conditions and any potential construction problems.

Cost. The total first cost if this alternative, exclusive of treatment, is currently estimated to be $1,261.000.

ALTERNATIVE 2

General. A second alternative for Gravelly Run consists of a diversion structure located near its mouth. This diversion alternative would include a dam, elevation 12 feet m.s.l., and a gravity conduit to divert the flow from Gravelly Run to Bailey Creek with subsequent treatment equal to that provided for Bailey Creek.

Site Description. The dam would be located approximately 200 feet downstream from the Continental Can bridge as shown on plate 14. The proposed gravity conduit would be located in a narrow saddle just upstream of the right abutment also shown on plate 14. The area along the line of the proposed conduit is heavily wooded with elevations ranging from +2 feet to +20 feet m.s.l. The diversion conduit terminates in a marsh within the flood plain of Bailey Creek.

Subsurface Conditions. The subsurface conditions for the dam are the same as those described for Alternative 1. Cutslopes near the proposed line of the gravity conduit indicate a silty and clayey sand to a depth of approximately 15 feet. It is believed that organics would be encountered in the Bailey Creek flood plain.

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Recommended Design. The purpose of the dam on Gravelly Run in conjunction with the diversion works would be to store and divert all runoff on the Gravelly Run watershed up to and including the 100-Year Flood. The elevation of the dam would be 12 feet m.s.l., compared to 18.4 feet m.s.l. for Alternative 1. No spillway would be required because the flow would be permanently diverted to Bailey Creek and treated in the same manner in which the discharge in Bailey Creek would be treated. In this alternative, the water would flow to Bailey Creek by gravity. However, if constructed in combination with a dam on Bailey Creek, a pumping station having a capacity of 325 c.f.s. would be required. In addition, the elevation of the dam would increase to 13.4 feet m.s.l.

It is recommended that an earth fill dam be adopted for the diversion structure. Approximately 400 feet of the existing Gravelly Run channel would require realignment to provide a smooth transition into the diversion conduit. The earth dam would be constructed of controlled fill to elevation +12 feet m.s.l. The dam would be approximately 600 feet in length with a 1 vertical to 3 horizontal upstream slope and a 1 vertical to 2.5 horizontal downstream slope. Riprap slope protection would be placed on the upstream and downstream slopes to elevations of +12 feet and +8.5 feet m.s.l., respectively. A typical dam section is shown on plate 13. The diversion works would consist of twin 96-inch diameter corrugated metal pipes approximately 1,000 feet in length. These pipes would be placed on a slope of 0.001. Loose riprap would be placed at both ends of the pipelines for erosion protection.

This alternative would require about 59 acres of land behind the dam. In addition, no bridges or other permanent structures would be affected. The following table summarizes the pertinent design associated with this alternative.

Table 18. PERTINENT DESIGN DATA FOR ALTERNATIVE 1

DAM STRUCTURE	
Elevation, ft. m.s.l.	12.0
Height, ft.	17.0
Top width, ft.	5.0
Length	600.0
Land Required, acres	59.0
Diversion	
Corr. metal pipes	2.0
Size - diameter, inches	96.0
Length, ft.	1,000.0

Potential Construction Problems. No major problems are anticipated during the construction of this alternative. Treatment of the left abutment is not considered necessary in this alternative because water would only be intermittently impounded. A temporary access bridge would be required for access to the Hopewell Sewage Treatment Plant during the placement of the diversion conduits.

Cost. The total first cost of this alternative is currently estimated to be $1,631,000.

ALTERNATIVE 3

General. Alternative 3 involves covering the contaminated flood plain of Gravelly Run with a 3-foot minimum layer of native cohesive material. A flow control structure would be necessary at the downstream end of the protected area to prevent seepage of Kepone from the watershed. Plate 15 shows the approximate extent of cover and the location of the control structure near the mouth of Gravelly Run.

Site Description. Approximately 30 acres of the Gravelly Run flood plain would be covered with a 3-foot minimum layer of native cohesive material. Of the entire area to be covered, 19.6 acres consist of woods which would have to be cleared prior to covering operations. The site of the proposed control structure is located just upstream from the mouth of Gravelly Run. The stream at this point is approximately 60 feet wide with a maximum depth of 7 feet. The right bank rises sharply to an elevation of +40 feet m.s.l. In contrast, the left bank is relatively flat with elevations ranging from +4 feet m.s.l. at the streambank to +6.5 feet m.s.l. at the base of an existing waste pond levee. The flood plain within this area is heavily wooded. The bottom elevation of the industrial waste pond is +8 feet m.s.l. The presence of this waste pond should not affect the integrity of the proposed structure. However, backfilling the existing pond should be anticipated for the concept study.

Subsurface Conditions. Boring DH-5 drilled in the vicinity of the proposed flow control structure encountered approximately 30 feet of organic clay (OH) overlying clean sands (SP) and gravels (GP). It is anticipated that these conditions are typical of the subsurface conditions under the low flood plain on the left bank of the stream and within the stream itself.

Recommended Design. A 3-foot minimum layer of native cohesive material is considered necessary in order to support the movement of heavy equipment on the flood plain during spreading operations. Initially, clearing operations would be required and all trees would be cut flush with the ground. After clearing the flood plain, typar filter cloth would be placed over the flood plain in sections to distribute the weight of the cohesive fill material and to allow heavy equipment to operate. Specifically, the cohesive material would be brought in by truck and spread with appropriate heavy equipment over the filter cloth. No compaction is required. The natural channel would be further protected by riprap. A layer of gravel bedding under the riprap would prevent puncturing of the typar filter cloth.

The proposed flow control structure would be approximately 140 feet wide with 4 feet of the structure at elevation 0.0 foot m.s.l., 56 feet at elevation +1.0 foot m.s.l., and the remaining section at +8 feet m.s.l. The construction will consist of 14 inch X 14 inch reinforced concrete "H" piles, spaced at 10-foot centers, and tongue and groove planking, placed horizontally between the piles. The 4-foot weir would be placed near the center of the existing channel to control normal flows. Riprap would be placed adjacent to and downstream of the control structure for erosion protection. A riprap thickness of approximately 3 feet has been assumed downstream of the 4-foot weir. Plate 16 shows details of the flow control structure. The following table summarizes the pertinent design data associated with this alternative.

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Table 19. PERTINENT DESIGN DATA FOR ALTERNATIVE 3

Depth of cover material, ft.	3.0
Typar filter cloth, yd^2	145,000.0
Amount of material required, c.y.	145,000.0
Amount of riprap required, c.y.	7,000.0
Gravel bedding, c.y.	7,000.0
Depth of "H" piling, ft.	40.0
Top elevation, ft. m.s.l.	8.0
Minimum elevation of discharge facility, ft. m.s.l.	0.0
Area to be covered, acres	30.0
Area to be cleared, acres	19.6

Potential Construction Problems. Clearing, spreading of the cohesive layer, and construction of the control structure would be hampered by limited access and poor subsurface conditions. Clearing operations would have to be conducted by using metal mats for moving logging equipment in and out of the marsh areas. Trees would be handled in a manner not to disturb the existing ground surface. With regard to construction of the flow control structure, pile driving operations would be restricted and expensive.

Cost. The total first cost of this alternative is currently estimated to be $1,524,000.

ALTERNATIVE 4

This alternative involves relocating the existing channel in Gravelly Run into either a concrete paved channel or a closed conduit and covering the contaminated flood plain with a 3-foot minimum impervious cover as discussed in Alternative 3.

In evaluating the two schemes for relocating the existing channel, it was determined that a paved channel would be the preferred solution. One of the main disadvantages of a closed conduit system is that it would be extremely difficult and expensive to accommodate the small tributaries of Gravelly Run in the closed system. Furthermore, the actual construction, including adequate supports, would be a tedious and expensive project in itself. In view of the above, it is believed that a concrete paved channel would be a more feasible scheme for relocating the existing channel.

The concrete paved channel would be trapezoidal in shape and extend from an elevation of 5 feet m.s.l. upstream in Gravelly Run to the control structure located near the mouth, as shown on plate 17. The remaining components of this alternative including the 3-foot cover and the flow control structure would be identical to Alternative 3.

It is important to note that the added cost of the paved channel would still be more than the cost of filling the existing channel as proposed in Alternative 3. In addition, the benefits of containing Kepone would be the same for the complete 3-foot covering proposed in Alternative 3 as the combination filling paved channel in Alternative 4. Due and to the fact that no additional benefits would be derived and the cost of a paved channel would be more than the filling alternative, Alternative 4 has been eliminated from further consideration.

ALTERNATIVE 5

This alternative for Gravelly Run is also similar to Alternative 3. Specifically, Alternative 5 calls for dredging a new channel adjacent to the existing channel, sealing the side slopes of the new channel to prevent seepage, and covering the contaminated flood plain up to elevation 5 feet m.s.l. as discussed in Alternative 3. In addition, a flow control structure would be required near the mouth of Gravelly Run.

The proposed channel would be dredged to a depth of about 3 feet and would extend from an elevation of 5 feet m.s.l. upstream in Gravelly Run to the flow control structure located near the mouth, as shown on plate 18. The actual dredging operation would have to be performed using a dragline. The dredged material, including tree root systems, would be truck hauled to a disposal area. The bottom of the new channel would have to be ripraped to prevent erosion. The other components of this alternative, including the 3-foot cover and the flow control structure, would be identical to Alternative 3. It should be noted that the sealing of the side slopes of the new channel would be accomplished with a 3-foot thick cover of the same native cohesive material used for covering the contaminated flood plain area.

Alternative 5, like Alternative 4, does not provide any additional benefits over and above those derived from Alternative 3. In addition, Alternative 5 would exhibit additional costs associated with dredging a new channel and disposal of dredged material. For this reason, Alternative 5 has also been eliminated from further consideration.

ALTERNATIVE 6

This alternative consists of dredging all contaminated material in Gravelly Run and placing the material in an appropriate disposal area. Tests have revealed that most of the Kepone in the sediments along Gravelly Run is in the upper 15 inches. In addition, the Kepone is confined to the bottom land sediments below elevation 5 feet m.s.l. For this reason, the extent of this plan has been based on the entire area below the 5-foot m.s.l. contour which is estimated to be 30 acres. The area to be dredged is shown on plate 19.

Studies indicate that the only practical method of dredging Gravelly Run within the 5-foot m.s.l. contour would be by dragline. Furthermore, the minimum reasonable depth to which dredging operations could be accomplished is estimated to be 3 feet. Prior to any dredging, the entire flood plain area below the 5-foot m.s.l. contour would have to be cleared. Of the 30 acres to be dredged, about 20 acres consist of woods and swamp. In this regard, all trees must be initially cut flush with the existing ground elevation. All tree root systems would be removed during the dragline dredging operation and truck hauled away with the dredged material to the disposal site.

In order to dredge all of the contaminated area in Gravelly Run to a depth of 3 feet by dragline, approximately 152,000 cubic yards of material would have to be handled. This volume estimate includes some material required for haul roads. The contaminated dredged material would be truck hauled to the selected disposal site. The effluent from the disposal area would be treated by appropriate treatment facilities.

As indicated in the section on "Special Studies," both upland and estuarine sites were initially considered for disposal areas. Studies revealed that the optimum area capable of handling all contaminated material from Gravelly Run, Bailey Creek, and Bailey Bay would be site 14 located in Bailey Bay, as shown on plate 9. Additional information regarding the proposed disposal area in Bailey Bay and the dragline dredging operations is discussed under the "Special Studies" section of the report.

The total first cost, exclusive of treatment, is currently estimated to be $1,026,000.

ALTERNATIVE 7

General. Similar to Alternative 1 for Gravelly Run, this alternative involves constructing a dam to elevation 25 feet m.s.l. near the mouth of Bailey Creek and treating all runoff from the watershed. It would be constructed with an emergency spillway in conjunction with a treatment facility.

Site Description. The proposed dam would be located at the mouth of Bailey Creek where the creek widens to approximately 1,600 feet, as shown on plate 20. At low tide the area within the proposed site is predominately a mud flat with elevations ranging from -1 foot to -4 feet m.s.l. The proposed abutments are heavily wooded and rise sharply from near 0.0 foot m.s.l. to +40 feet m.s.l. on the left abutment and to +100 feet m.s.l. on the right abutment.

Subsurface Conditions. Three borings, DH-7, 9, and 13, were drilled in the vicinity of the proposed alternative. The three borings indicated weight-of-hammer, organic clay, and peat to a depth of approximately 41 feet. The exception was DH-13 which was drilled in Bailey Bay and encountered fine sands (SM) at a depth of 27.5 feet. An upper stratum of silty sand (SM) with some organic silt was encountered in the top 13 feet of DH-8, however, the standard penetration tests indicated weight-of-hammer material. Additional deeper borings would be needed in this area to adequately define a firm bearing stratum. It is assumed that the poor foundation conditions mentioned above exist across the entire width of the creek.

No borings were drilled in the abutments. However, field observations of the exposed substrata indicated that the soil consists of clayey sands (SC) and silty clays (CL). These soils would provide a firm foundation and an impervious cutoff.

Recommended Design. The purpose of the dam would be to store all runoff on the Bailey Creek watershed up to and including the 100-Year Flood. The runoff would pass through a treatment facility for treatment and be discharged into the James River. Runoff in excess of the 100-Year Flood would be discharged directly into the James River without any treatment. The required capacity of the treatment facility would vary, depending upon the selected retention period. For example, if water was stored for 12 days, a 50 M.G.D. facility would be needed; whereas if the water was stored for 3-3/4 days, a 150 M.G.D. plant would be required.

This alternative would require about 1,060 acres of land, and the dam would provide 7,150 acre-feet of storage. In this regard, one bridge would have to be relocated due to the ponding elevation associated with the 100-Year Flood. Specifically, the eastbound Route 10 crossing would have to be reconstructed at a higher elevation. In addition, seven residential structures would have to be relocated as a result of the potential ponding.

Because of the poor subsurface conditions, an earth dam is recommended in lieu of a concrete structure. The poor subsurface conditions also prevent the construction of an earth dam by conventional means. Therefore, a hydraulic fill with an impervious cutoff and riprap slope protection is recommended for the design of the earth structure. The dam would have a length of about 1,700 feet. It would have a top width of 15 feet with side slopes of 1 on 3 on the upstream side and 1 on 2.5 on the downstream side. The height of the dam would be about 27 feet, with a top elevation of 25 feet m.s.l. which includes 3 feet of freeboard. The upstream side of the dam would be protected by riprap to the top; whereas, the downstream side would be protected to elevation 8.5 feet m.s.l. The 8.5 feet m.s.l. is the elevation of the 100-Year Flood in the James River.

To minimize the effects of settlement and isolated shear failures, approximately 9 feet of muck or organics would be removed prior to placement of the hydraulic fill. The placement of the fill would be performed in two stages to prevent mud waves and, possibly, catastrophic shear failures. The first placement would be approximately 9 feet thick at the center of the dam and would have maximum slopes of 1 vertical to 50 horizontal. The second stage would be placed hydraulically and shaped by dragline to the 1 on 3 and 1 on 2.5 slopes desired. To compensate for the anticipated settlement, it is recommended that 5 feet of overbuild be added to the design height.

Filter cloth, bedding, and riprap would be placed as soon as possible to protect the easily erodible hydraulic fill. A 1-foot layer of gravel should be placed on the crest to serve as a working mat for equipment. After the riprap had been placed, a 4-foot wide slurry trench would be constructed upstream of the dam centerline to a depth of at least 15 feet below the bottom of the hydraulic fill. The impervious trench would run the entire length of the dam and tie into the abutments. A typical section of the dam is shown on plate 21.

In addition to the dam, an emergency spillway would be constructed. This spillway was designed to accommodate floods up to and including the Standard Project Flood and has a top elevation of 15.9 feet m.s.l. The proposed emergency spillway would be located in the left abutment to minimize the effects of settlement. The spillway would have 1 vertical to 2 horizontal side slopes and a crest width of 100 feet. A 1-foot thick reinforced concrete liner is proposed to prevent erosion. Energy dissipators are not included with this design.

The following table summarizes the pertinent design data associated with this alternative.

Table 20. PERTINENT DESIGN DATA FOR ALTERNATIVE 7

DAM STRUCTURE (100-Year Flood)	
Elevation, ft. m.s.l.	25.0
Height, ft.	27.0
Top width, ft.	15.0
Length, ft.	1,700.0
Area of watershed, sq. mi.	20.0
Spillway	
Length, ft.	100.0
Elevation, ft. m.s.l.	15.9
Storage, acre ft.	7,150.0
Land Required, acres	1,060.0
Required capacity of treatment facility	
12 days	50 M.G.D.
5-1/2 days	100 M.G.D.
3-3/4 days	150 M.G.D.

Potential Construction Problems. It is anticipated that problems might arise during the placement of the hdraulic fill. Based on past experience with similar conditions, mudwaves can be developed in soft foundation conditions if the hydraulic fill is not properly baffled and spread with very flat slopes. Eroson from tidal action and interior flow will also be a continuous probem until the riprap protection is completed. Temporary stream diverson or completion of the treatment facility prior to construction of te dam would provide adequate protection against normal interior unoff. In addition to the above problems, placement of the slurry tench might also incur several difficulties. These difficulties wuld include the mobilization of the equipment on the embankment and theexcavation of the trench within the granular fill.

Cost. The total first cost excludig any treatment facility, for this alternative is currently estimated o be $9,172,000.

ALTERNATIVE 8

General. This alternative for Bailey Creek is basically the same as Alternative 3 for Bailey Creek. It involves covering the contaminated flood plain of Bailey Creek with a 3-foot minimum layer of native cohesive material. A flow control structure would be necessary at the downstream end of the protected area to prevent seepage of Kepone from the watershed. Plate 22 shows the extent of cover and the location of the control structure near the mouth of Bailey Creek.

Site Description. Approximately 464 acres of the Bailey Creek flood plain would be covered with a 3-foot minimum layer of native cohesive material. Most of the flood plain consists of woods which would have to be cleared prior to covering operations. The site of the proposed flow control structure would be located just downstream of the Route 10 bridge. The creek at this point is approximately 100 feet wide with an average elevation of -2 feet m.s.l. The flood plain outside the main channel is marshy with some tree cover. The flood plain in this area is approximately 800 feet wide with elevations ranging from 0 to +1 foot m.s.l.

Subsurface Conditions. Boring DH-10 and subsurface data received from the State Highway Department for the Route 10 bridge indicate approximately 20 feet of organic silt (OL) overlying a silty sand (SM). This profile is typical of the subsurface conditions in the channel. Based on the data obtained from the design of the existing Route 10 bridge, it is anticipated that the organic layer decreases to approximately 3 feet outside the channel. However, for the purpose of designing the flow control structure, it was assumed that the organic stratum was constant for the complete width of the flood plain.

Recommended Design. Similar to Gravelly Run, a 3-foot minimum layer of native cohesive material is considered necessary in order to support the movement of heavy equipment on the flood plain during spreading operations. Initially, clearing operations would be required and all trees would be cut flush with the ground. After clearing the flood plain, typar filter cloth would be placed over the flood plain in sections to distribute the weight of the cohesive fill material and to allow heavy equipment to operate. The cohesive material would be brought in by truck and spread with appropriate heavy equipment over the filter cloth. No compaction is required. The natural channel would be further protected by riprap. A layer of gravel bedding under the riprap would prevent puncturing of the typar filter cloth.

The proposed control structure would consist of 14 inch x 14 inch reinforced concrete "H" piles and tongue and groove reinforced concrete planking. The control structure would have a 4-foot wide weir section constructed at elevation -2 feet m.s.l. to control normal flows. The remaining portion of the control structure would be constructed with a width of approximately 860 feet and an overflow elevation of +2 feet m.s.l. The latter elevation would regulate flows during flood conditions. The abutments would have a minimum elevation of +8 feet m.s.l. Riprap would be placed downstream of the overflow structure for erosion protection. A riprap thickness of 3 feet has been assumed for the area just downstream of the 4-foot weir section. Plate 23 shows a typical section of the proposed flow control structure. Dimensions and elevations would change to correspond to those indicated in table 21.

The following table summarizes the pertinent design data associated with this alternative.

Table 21. PERTINENT DESIGN DATA FOR ALTERNATIVE 8

Depth of cover material, ft.	3
Typar filter cloth, yd.	2,246,000
Amount of material required, c.y.	2,246,000
Amount of riprap required, c.y.	78,000
Gravel bedding, c.y.	78,000
Depth of "H" piling, ft.	40
Top elevation, ft. m.s.l.	8
Elevation of crest, ft. m.s.l.	4
Minimum elevation of discharge facility, ft. m.s.l.	0
Area to be covered, acres	464
Area to be cleared, acres	410

Potential Construction Problems. Like Gravelly Run, clearing, spreading of the cohesive layer, and construction of the control structure would be hampered by limited access and poor subsurface conditions. Clearing operations would have to be conducted by using metal mats for moving logging equipment in and out of the marsh areas. Trees would be handled in a manner not to disturb the existing ground surface. With regard to construction of the flow control structure, driving piles would present the major problem. Because of the shallow water depths and soft subsurface conditions, access for heavy equipment would be limited.

Cost. The total first cost of this alternative is currently estimated to be $20,845,000.

ALTERNATIVE 9

This alternative involves relocating the existing channel in Bailey Creek into either a concrete paved channel or a closed conduit and covering the contaminated flood plain with a 3-foot minimum impervious cover up to elevation 5 feet m.s.l. as discussed in Alternative 8.

In evaluating the two schemes for relocating the existing channel, it was determined that a paved channel would be the preferred solution. One of the main disadvantages of a closed conduit system is that it would be extremely difficult and expensive to accommodate the small tributaries of Bailey Creek into the closed system. Furthermore, the actual construction including adequate supports, would be a tedious and expensive project in itself. In view of the above, it is believed that a concrete paved channel would be a more feasible scheme for relocating the existing channel.

The concrete paved channel would be trapezoidal in shape and extend from an elevation of 5 feet m.s.l. just upstream of the Route 156 bridge on Bailey Creek to the control structure located near the mouth as shown on plate 24. The other components of this alternative, including the 3-foot cover and the flow control structure, would be identical to Alternative 8.

It is significant to note that the added cost of the paved channel would still be more than the cost of filling the existing channel as proposed in Alternative 8. In addition, the benefits of containing Kepone would be the same for the complete 3-foot covering proposed in Alternative 8 as the combination covering and paved channel in Alternative 9. Due to the fact that no additional benefits would be derived and the cost of a paved channel would be more than the filling alternative, Alternative 9 has been eliminated from further consideration.

ALTERNATIVE 10

This alternative for Bailey Creek is also similar to Alternative 8. Specifically, Alternative 10 calls for dredging a new channel adjacent to the existing channel, sealing the side slopes of the new channel to prevent seepage, and covering the contaminated flood plain up to elevation 5 feet m.s.l. In addition, a flow control structure would be required near the mouth of Bailey Creek.

The proposed channel would be dredged to a depth of about 3 feet and would extend from an elevation of 5 feet m.s.l. just upstream of Route 156 in Bailey Creek to the flow control structure located near the mouth, as shown on plate 25. The actual dredging operation would have to be performed using a dragline. The dredged material, including tree root systems, would be truck hauled to a disposal area. The bottom of the new channel would have to be riprapped to prevent erosion. The other components of this alternative, including the 3-foot cover and the flow control structure, would be identical to Alternative 8. It should be noted that the sealing of the side slopes of the new channel would be accomplished with a 3-foot thick cover of the same native cohesive material used for covering the contaminated flood plain area.

Alternative 10, like Alternative 9, does not provide any additional benefits over and above those derived from Alternative 8. In addition, Alternative 10 would exhibit additional costs associated with dredging a new channel and disposal of dredged material. For this reason, Alternative 10 has also been eliminated from further consideration.

ALTERNATIVE 11

This alternative for Bailey Creek is similar to Alternative 6 for Gravelly Run. Specifically, Alternative 11 calls for dredging all contaminated material in Bailey Creek and placing the material in an appropriate disposal area. Tests have revealed that most of the Kepone in the sediments along Bailey Creek is in the upper 15 inches. In addition, the majority of the Kepone is confined to the bottom land sediments below elevation 5 feet m.s.l. For this reason, the extent of this plan has been based on the entire area below the 5-foot m.s.l. contour which is estimated to be 513 acres. The approximate area to be dredged is shown on plate 26.

Like Gravelly Run, studies indicate that the only practical method of dredging Bailey Creek within the 5-foot m.s.l. contour would be by dragline. Furthermore, the minimum reasonable depth to which dredging operations could be accomplished is estimated to be 3 feet. Prior to any dredging, the entire flood plain area below the 5-foot m.s.l. contour would have to be cleared. Of the total area to be dredged, 513 acres, about 435 acres consist of woods and swamps. In this regard, all trees must be initially cut flush with the existing ground elevation. All tree root systems would be removed during the dragline dredging operations and truck hauled with the dredged material to the disposal site.

In order to dredge all of the contaminated area in Bailey Creek to a depth of 3 feet by dragline, approximately 2,548,000 cubic yards of material would have to be truck hauled to the disposal area. This volume estimate includes some material required for haul roads. The contaminated dredged material would be truck hauled to the selected disposal site. The effluent from the disposal area would be treated by required treatment facilities.

As indicated in the section on Special Studies, both upland and estuarine sites were initially considered for disposal areas. Studies revealed that the optimum area, capable of handling all contaminated material from Gravelly Run, Bailey Creek, and Bailey Bay, would be site 14 located in Bailey Bay, as shown on plate 9. Additional information regarding the proposed disposal area in Bailey Bay and the dragline dredging operations is presented under the "Special Studies" section of this report.

The total first cost of this alternative, exclusive of treatment is currently estimated to be $16,010,000.

ALTERNATIVE 12

General. Alternative 12, involving the diversion of flows in Bailey Creek upstream of the existing city-owned sewage treatment plant, would be combined with another alternative to solve the Kepone problem in the polluted portion below the treatment plant. Specifically, a dam would be constructed upstream of the sewage treatment plant and unpolluted runoff would be diverted to an adjacent watershed. Two schemes were considered for diverting the upstream flow. One method involves an overland pressure conduit. The other scheme would consist of a closed-gravity conduit. The dam associated with the gravity diversion would be built to an elevation of 45 feet m.s.l., whereas a 46-foot m.s.l. dam would be required for the pressure conduit diversion scheme in order to provide 3 feet of freeboard.

Site Description. The proposed site of the dam would be located approximately 600 feet upstream of the Route 156 bridge, as shown on plate 27. The site is characterized by marshy terrain in the lower lying areas and heavily wooded terrain in the upper elevations. Elevations range from a low of +4 feet m.s.l. in Bailey Creek to a high of +100 feet m.s.l. on the right abutment. An emergency spillway would be located approximately 400feet east of Route 156 between Manchester Run and Bailey Creek. The site is predominately wooded except where the proposed spillway crosses Route 646.

The route of the proposed overland pressure conduit system would generally follow State Route646 to Chappell Creek, a distance of approximately 17,000 feet, as shown on plate 27. The gravity conduit system would run along the existing Bailey Creek channel approximately 17,000 feet to the James River, as shown on plate 28.

Subsurface Conditions. Two borings, DH-11 and 12, were drilled in the vicinity of the proposed dam. The cumulative results of these borings indicated approximately 16 feet of clayey sand (SC) overlying clean sands (SP) and gravels (GP). Boring DH-11, drilled in the flood plain near Bailey Creek, encountered a 1-foot layer of organic clay (OH) overlying the clayey sand (SC). The underlying sands (SP) and gravels (GP) were saturated and yielded blow counts in excess of 35. This stratum extended to a depth of 35 feet where very fine sands (SM) and silts (ML) were encountered. This lower stratum represents the upper boundary of the Tertiary marine deposits.

Recommended Design. The purpose of the upstream dam would be to store all runoff above the dam in the Bailey Creek watershed up to and including the 100-Year Flood. The unpolluted runoff would be diverted by means of either a pressure conduit or a gravity conduit to an adjacent watershed. Runoff in excess of the 100-Year Flood would be discharged directly into the polluted portion of Bailey Creek.

The 45-foot m.s.l. dam with the gravity diversion scheme would require about 405 acres of land and provide 3,800 acre-feet of storage. The 46-foot m.s.l. dam with the pressure conduit diversion would require about 428 acres of land and 3,800 acre-feet of storage. No bridges would have to be relocated due to the ponding elevation associated with the 100-Year Flood. However, 25 residential structures would have to be relocated. It is recommended that the proposed dam be constructed from controlled earth fill to elevations of +45 feet m.s.l. or +46 feet m.s.l. depending on the method of diversion. Based on the available topographic data, the dam would have a crest length of approximately 1,600 feet. The upstream and downstream slopes would be 1 vertical to 2.5 horizontal. A crest width of 20 feet is recommended for access after completion of construction. The upstream slope would require riprap protection; whereas, a grass cover would suffice for the downstream slope. In addition to the riprap protection, special foundation treatment would be required to control seepage. These treatment measures include an upstream impervious blanket, downstream relief wells, and a downstream toe drain. Because the dam would function as a dry dam and only intermittently impound water, these special treatment measures may be deleted after an indepth design is performed. Plate 29 shows a typical section of the dam.

In addition to the dam, an emergency spillway would be constructed. This spillway was designed to accommodate floods up to and including the Standard Project Flood. It would have a crest width of 200 feet and a crest elevation of +37 feet m.s.l. The spillway would be approximately 1,000 feet in length with 1 vertical to 2 horizontal side slopes. A 1-foot reinforced concrete liner would be required for erosion protection. Energy dissipators were not considered.

The proposed overland pressure conduit system would consist of two 108-inch diameter asbestos bonded corrugated pipes, a pumping station at the dam site, and an energy dissipator at the pipe outfall. The pipes would be buried with a minimum cover of 3 feet.

The proposed route would generally follow State Route 646 to Chappell Creek, a distance of approximately 17,000 feet. A pumping station having a capacity of 325 c.f.s. and an energy dissipator would be required.

The proposed gravity conduit system would carry clean water from the proposed dam to the James River. The closed system would consist of two 120-inch diameter asbestos bonded corrugated pipes supported on piles in the marshy area and on the existing subgrade in the higher elevations. The concrete piles and pile caps would be placed on 40-foot centers in the marshy lowlands to provide support and counteract uplift.

The following table summarizes the pertinent design data associated with this alternative.

Table 22. PERTINENT DESIGN DATA FOR ALTERNATIVE 12

Dam 600 feet upstream of Route 156 bridge	
DAM	
Top elevation, ft. m.s.l.	
Gravity diversion	45
Pressure conduit	46
Height, ft.	
Gravity diversion	40
Pressure conduit	41
Top width	10
Length, ft.	1,600
SPILLWAY - Located between Manchester Run and Bailey Creek	
Length, ft.	200
Elevation, ft. m.s.l.	37
Storage, acre ft.	
Gravity diversion	3,800
Pressure conduit	3,800
Land required, acres	
Gravity diversion	405
Pressure conduit	420
GRAVITY CONDUIT	
Pipe	
Size, diameter inch.	120
Number	2
Length, ft.	17,000
Type	Welded steel
Capacity, c.f.s.	1,400
PRESSURE CONDUIT	
Diversion pipe	
Size, diameter inch.	108
Number	2
Length, ft.	17,000
Type	Welded steel
Capacity, c.f.s.	325

Potential Construction Problems. No major construction problems are anticipated for the proposed dam, emergency spillway, and pressure conduit. The major problem associated with the gravity conduit would be limited access. The limited access would increase the cost of the pile driving operation.

Cost. The total first cost of this alternative including downstream treatment is currently estimated to be $22,120,000 using the gravity diversion and $34,800,000 for the pressure conduit scheme. Due to the fact that both diversion schemes accomplish the same objective, the gravity diversion scheme which is less costly was the only one considered for further evaluation.

ALTERNATIVE 13

This alternative would require dredging all contaminated material in Bailey Bay and pumping it into a predetermined disposal area. For the purpose of this study, all sediments in Bailey Bay containing Kepone concentrations of 0.1 ppm or greater were considered necessary for removal. Plate 30 shows the existing Kepone concentrations in Bailey Bay and plate 31 shows the extent of the required dredging. It is also important to note that tests have revealed that most of the Kepone in the sediments in Bailey Bay is in the upper 15 inches. Utilizing the Mud Cat dredge as recommended from the section on "Dredging Technology," approximately 1.8 million cubic yards would have to be dredged from all of Bailey Bay.

As indicated in the section on "Disposal Areas", both upland and estuarine sites were initially considered for disposal areas. Studies revealed that the optimum area capable of handling all contaminated material from Gravelly Run, Bailey Creek, and Bailey Bay would be site 14 located in Bailey Bay as shown on plate 9. Since the selected disposal area for this study takes up a portion of Bailey Bay, this alternative to dredge the entire bay is no longer applicable. However, a subsequent alternative (Alternative 17) addresses dredging Gravelly Run and Bailey Creek as well as the portion of Bailey Bay outside the selected disposal area. For the purpose of evaluation, however, a cost estimate was made of dredging all of Bailey Bay. It was assumed that the material would be disposed of behind a dam constructed at the mouth of Bailey Creek as described in Alternative 15. Using Bailey Creek as the disposal area, the cost exclusive of disposal of dredging all of Bailey Bay, excluding disposal, is currently estimated to be $6,494,000.

ALTERNATIVE 14

General. As an alternative for preventing the escape of Kepone from Gravelly Run, Bailey Creek, and Bailey Bay, consideration has been given to constructing a levee across Bailey Bay and treating the entire discharge from Gravelly Run and Bailey Creek.

Site Description. As shown on plate 32, the levee would extend from a point approximately 1 mile east of City Point across Bailey Bay to Jordan Point, a distance of about 14,250 feet. The alignment as shown takes into consideration that the toe of the levee should be at least 1,000 feet off the existing James River channel. The levee would be constructed with an emergency spillway in conjunction with required treatment facilities.

Subsurface Conditions. From a foundation standpoint, the subsurface conditions in Bailey Bay are extremely poor. Borings taken in Bailey Bay indicate organic deposits up to 50 feet thick. These organic deposits are composed of peat and organic clays and silts.

Recommended Design. The levee would be constructed to a design height of 10 feet m.s.l. In order to allow for anticipated settlement and freeboard, the levee would be overbuilt initially by 5 feet. A typical section of the levee is shown on plate 10. The levee would be constructed with hydraulic fill with an impervious bentonite and sand slurry cutoff trench and riprap protection on the outside levee slope. The hydraulic fill would be placed in two stages to prevent catastrophic shear failures. The first placement would constitute a working berm with a thickness of 7 feet above the mudline at the center axis of the levee with slopes of 1 vertical to 20 horizontal. The second stage would include placement of 10 feet of hydraulic fill with 1 vertical to 5 horizontal slopes. After placement of the second stage had been completed, the slopes would be reworked or shaped to 1 vertical to 3 horizontal. Filter cloth, bedding material, and riprap would then be placed on the outside levee slope for protection of the easily erodible hydraulic fill material. A 1-foot layer of gravel placed on the 20-foot wide levee crest is proposed for a working roadbed for equipment. To prevent seepage, a 3-foot wide slurry trench would be constructed to a depth of at least 10 feet below the bottom of the hydraulic fill. The slurry trench would be located on the inside levee slope and would run the entire length of the dam.

Potential Construction Problems. The main construction problem would result from the poor subsurface conditions. Settlement is difficult to estimate.

Cost. The total first cost of the alternative, excluding the treatment facility, is currently estimated to be $6,764,000.

ALTERNATIVE 15

General. This alternative involves all three contaminated areas under study--Bailey Bay, Bailey Creek, and Gravelly Run. A dam would be constructed near the mouth of Bailey Creek. Bailey Bay would be dredged and the area behind the dam on Bailey Creek would be used as a disposal area. The alternative also involves constructing a dam at the mouth of Gravelly Run and diverting the discharge into Bailey Creek. A treatment facility would be required at the mouth of Bailey Creek to treat all effluent from the disposal area.

Site Description. The proposed dam on Bailey Creek would be located at the mouth of Bailey Creek where the creek widens to approximately 1,600 feet, as shown on plate 33. At low tide the area within the proposed site is predominately a mudflat with elevations ranging from -1 foot to -4 feet m.s.l. The proposed abutments are heavily wooded and rise sharply from near 0.0 foot m.s.l. to +40 feet m.s.l. on the left abutment and to +100 feet m.s.l. on the right abutment.

The site of the proposed dam on Gravelly Run would be located approximately 200 feet downstream of the Continental Can bridge, as also shown on plate 33. A majority of the site is covered by marsh grass and small bushes. Elevations within this area range from -2 feet to +2 feet m.s.l. The flood plain is approximately 600 feet wide at this point. The right abutment is heavily wooded with elevations rising from +2 feet m.s.l. in the flood plain to +30 feet m.s.l. The left abutment is honeycombed by a series of industrial waste ponds which range in depth from 5 feet to 8 feet. Topographic surveys would be needed in this area to define the limits and actual depths of these ponds.

Subsurface Conditions. Three borings, DH-7, 9, and 13 were drilled in the vicinity of the proposed Bailey Creek dam. The three borings indicated weight-of-hammer, organic clay, and peat to a depth of approximately 41 feet. The exception was DH-13 which was drilled in Bailey Bay and encountered fine sands (SM) at a depth of 27.5 feet. An upper stratum of silty sand (SM) with some organic silt was encountered in the top 13 feet of DH-8, however, the standard penetration tests indicated weight-of-hammer material. Additional deeper borings would be needed in this area to adequately define a firm bearing stratum. It is assumed that the poor foundation conditions mentioned above exist across the entire width of the creek.

No borings were drilled in the abutments. However, field observations of the exposed substrata indicated that the soil consists of clayey sands (SC) and silty clays (CL). These soils would provide a firm foundation and an impervious cutoff.

No borings were drilled in the vicinity of the proposed dam on Gravelly Run. However, based on field observations of open excavations within the area and boring logs from the new Hopewell Sewage Treatment Plant, a soil profile was developed for the proposed site. It is anticipated that approximately 4 feet of soft organics and loose, fine sands overlie the flood plain. Underlying this upper cover are clayey sands and silty sands to a depth of at least 20 feet. The right abutment consists of fine to medium sands (SC-SM) with varying percentages of fines. The soil conditions in the left abutment are similar to the right abutment except where the upper 5 to 8 feet of material has been excavated to construct levees for the industrial waste ponds. These areas would require filling prior to construction of the dam.

Recommended Design. The purpose of the dam on Bailey Creek would be to store all runoff on the Bailey Creek watershed, as well as the diverted flows from the Gravelly Run watershed up to and including the 100-Year Flood. In addition, approximately 1,000,000 cubic yards of dredged material from Bailey Bay would be initially pumped into the area behind the dam on Bailey Creek. This material would be that required to dredge the portions of Bailey Bay where Kepone concentrations are 0.1 ppm or greater.

The runoff from Bailey Creek and Gravelly Run would pass through a treatment facility for treatment and be discharged into the James River. Runoff in excess of the 100-Year Flood would be discharged directly into the James River without any treatment. The required capacity of the treatment facility would vary, depending upon the selected retention period. For example, if water was stored for 45-1/2 days, a 50 M.G.D. facility would be needed, whereas, if the water was stored for 12 days, a 150 M.G.D. plant would be required.

This alternative would require a total of about 1.167 acres of land behind the dams plus 88.4 acres in Bailey Bay. In addition, two bridges must be relocated because of the potential flood pool elevations. Specifically, the two Route 10 bridges downstream on Bailey Creek. Both dams would provide 7,185 acre-feet of storage. No commercial or residential structures would be affected by this alternative.

Because of the poor subsurface conditions, an earth dam is recommended in lieu of a concrete structure on Bailey Creek. The poor subsurface conditions also prevent the construction of an earth dam by conventional means. Therefore, a hydraulic fill with an impervious cutoff and riprap slope protection is recommended for the design of the earth structure. The dam on Bailey Creek would have a top width of 15 feet with side slopes of 1 on 2.5. The height of the dam would be about 33.5 feet, with a top elevation of 26.5 which includes 3 feet of freeboard. The upstream side of the dam would be protected by riprap to the top and would be protected to the elevation of the 100-Year Flood in the James River, 8.5 feet m.s.l., on the downstream side.

To minimize the effects of settlement and isolated shear failures, approximately 9 feet of muck or organics would be removed prior to placement of the hydraulic fill. The placement of the fill would be performed in two stages to prevent mudwaves and, possibly, catastrophic shear failures. The first placement would be approximately 9 feet thick at the center of the dam and would have maximum slopes of 1 vertical to 50 horizontal. The second stage would be placed hydraulically and shaped by dragline to 1 vertical to 2.5 horizontal. To compensate for the anticipated settlement, it is recommended that 5 feet of overbuild be added to the design height.

Filter cloth, bedding, and riprap would be placed as soon as possible to protect the easily erodible hydraulic fill. A 1-foot layer of gravel should be placed on the crest to serve as a working mat for equipment. After the riprap has been placed, a 4-foot wide slurry trench would be constructed upstream of the dam centerline to a depth of at least 15 feet below the bottom of the hydraulic fill. The impervious trench would run the entire length of the dam and tie into the abutments.

In addition to the dam, an emergency spillway would be constructed. The proposed emergency spillway would be located in the left abutment to minimize the effects of settlement. The spillway would have 1 vertical to 2 horizontal side slopes and a crest width of 100 feet. A 1-foot thick reinforced concrete liner is proposed to prevent erosion. Energy dissipators are not included with this design. This spillway was designed to accommodate floods up to and including the Standard Project Flood. The spillway would be paved with concrete and would have a top elevation of 16.9 feet m.s.l.

Similar to the dam on Bailey Creek, the dam on Gravelly Run would be an earth fill structure. The dam would have a top width of 5 feet with side slopes of 1 on 3 on the upstream side and 1 on 2.5 on the downstream side. The height of the dam would be about 18 feet, with a top elevation of 13.4 m.s.l. which includes 3 feet of freeboard. The upstream side of the dam would be protected by riprap to the top and would be protected to elevation 8.5 feet m.s.l. on the downstream side. As previously stated, the 8.5 feet m.s.l. is the elevation of the 100-Year Flood in the James River.

The dam would have a length of approximately 700 feet. Prior to placement of the earth fill, approximately 3 feet of material would be removed and replaced with properly compacted fill. In addition to treating the foundation directly under the dam, a slurry cutoff trench, approximately 4 feet wide and 20 feet deep, shall be placed in the left abutment to form an impervious cutoff. The cutoff would be carried a distance of approximately 300 feet into the left abutment. Waste ponds within the path of the cutoff would be backfilled to the existing grade. After the cutoff has been placed, the earth dam would be constructed to the design grade.

No emergency spillway would be required for the dam on Gravelly Run because the flow would be permanently diverted to Bailey Creek and treated in the same manner in which the discharge in Bailey Creek would be treated. The diversion works consist of two 96-inch corrugated metal pipes. A pumping station would be required to divert the flow.

The following table summarizes the pertinent design data associated with this alternative.

Table 23. PERTINENT DESIGN DATA FOR ALTERNATIVE 15

BAILEY CREEK	
Dam Structure	
Elevation, ft. m.s.l.	26.5
Height, ft.	33.5
Top Width, ft.	20.0
Spillway	
Length, ft.	100.0
Crest elevation, ft. m.s.l.	16.9
GRAVELLY RUN	
Dam Structure	
Elevation, ft. m.s.l.	13.4
Height, ft.	18.0
Top Width, ft.	5.0
Length, ft.	600.0
Spillway	
Length, ft.	100.0
Crest elevation, ft. m.s.l.	8.5
Diversion	
Pressure conduit, ft.	1,000.0
Pump Station, c.f.s.	325.0
Total Storage, acre ft.	7.185.0
Total Land Required, acres	1,167.0

REQUIRED CAPACITY OF TREATMENT FACILITY

45-1/2 days	50 M.G.D.
19 days	100 M.G.D.
12 days	150 M.G.D.

Potential Construction Problems. It is anticipated that problems might arise during the placement of the hydraulic fill. Based on past experience with similar conditions, mudwaves can be developed in soft foundation conditions if the hydraulic fill is not properly baffled and spread with very flat slopes. Erosion from tidal action and interior flow would also be a continuous problem until the riprap protection was completed. Temporary stream diversion or completion of the treatment facility prior to construction of the dam would provide adequate protection against normal interior runoff. In addition to the above problems, placement of the slurry trench might also incur several difficulties. These difficulties would include the mobilization of the equipment on the embankment and the excavation of the trench within the granular fill.

Cost. The total first cost for this alternative, excluding the treatment facility, are currently estimated to be $26,931,000.

ALTERNATIVE 16

This alternative involves constructing a levee from approximately 1 mile east of City Point extending across Bailey Bay to Jordan Point as shown on plate 34 and using the confined area for maintenance dredging of the James River. All effluent from the disposal area would be treated with facilities to be designed later. The only difference between this alternative and Alternative 14 is the use of the confined area behind the levee as a disposal area. Since Alternative 14 could also include the use of the confined area as a disposal site for future maintenance dredging in the James River, Alternative 16 can be eliminated from further consideration.

ALTERNATIVE 17

This alternative is a combination of dredging alternatives for Gravelly Run, Bailey Creek, and Bailey Bay. Specifically, this plan would require constructing a levee from Jordan Point to the east side of

Bailey Creek and using the confined area as a disposal area for dredging the remainder of Bailey Bay and all contaminated areas in Bailey Creek and Gravelly Run. The proposed disposal area coincides with site 14 outlined in the previously discussed dredging alternatives and is also shown on plate 35.

Tests have revealed that most of the Kepone in the sediments in Bailey Bay, as well as Gravelly Run and Bailey Creek, is in the upper 15 inches. In addition, the majority of the Kepone in Gravelly Run and Bailey Creek is confined to the bottom land sediments below elevation 5 feet m.s.l. For this reason, dredging of these areas would include the entire area below the 5-foot m.s.l. contour. All of Bailey Bay outside the proposed disposal area with Kepone concentration of 0.1 ppm or greater would be dredged as a part of this alternative.

Studies indicate that the only practical method of dredging Gravelly Run and Bailey Creek below the 5-foot m.s.l. contour would be by dragline. Furthermore, the minimum reasonable depth to which dredging operations could be accomplished is estimated to be 3 feet. Prior to any dredging, the entire flood plain area on both streams below the 5-foot m.s.l. contour would have to be cleared. On Gravelly Run, about 30 acres would be dredged of which 20 acres would have to be initially cleared of woods. Approximately 513 acres would be dredged on Bailey Creek, with 435 acres requiring the clearing of trees. With regard to clearing operations, all trees must be initially cut flush with the existing ground elevation. All tree root systems would be removed during the dragline dredging operations and truck hauled to the disposal area in Bailey Bay. In order to dredge all of the contaminated area below the 5-foot m.s.l. contour in Gravelly Run and Bailey Creek to a depth of 3 feet by dragline, approximately 152,000 cubic yards and 2,548,000 cubic yards of material would have to be handled, respectively.

Due to the shallow depths in Bailey Bay and the uncertainties associated with mobilizing the Oozer to the United States, the Mud Cat dredge is considered to be the best plant for estimating the cost of dredging the remaining portion of Bailey Bay outside of the disposal levee shown on plate 35. Approximately 1,321,000 cubic yards of material must be dredged from Bailey Bay outside the disposal area in accordance with the criteria previously established in this report requiring the removal of all sediments with Kepone concentrations in excess of 0.1 ppm. Thus, a total of about 4,021,000 cubic yards of material must be removed from Gravelly Run, Bailey Creek, and Bailey Bay.

Additional information regarding the proposed disposal area in Bailey Bay as well as the dragline and Mud Cat dredging operations, is discussed under the "Special Studies" section of this report.

The total first cost associated with dredging Gravelly Run, Bailey Creek, and Bailey Bay, using the proposed disposal area in Bailey Bay, excluding treatment, is currently estimated to be $28,559,000.

ALTERNATIVE 18

This is another alternative involving Bailey Bay, Bailey Creek, and Gravelly Run. Basically, the plan would require covering the entire contaminated area with an impervious blanket to a depth which would allow natural drainage patterns and canals to develop, as shown on plate 36. The problem with this alternative is that there are no known methods to fill the area with impervious material unless the area is diked to control sedimentations. If the area was diked, this alternative would be similar to Alternatives 14 and 16. In addition, if drainage patterns were to develop naturally, there is no assurance that the new bottom or invert elevations would be above the location of Kepone in Bailey Bay. Furthermore, there could be a severe problem with erosion and seepage along the outer edges of the fill area.

In view of the disadvantages associated with this alternative, it has also been eliminated from further consideration.

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ENVIRONMENTAL IMPACT OF ALTERNATIVES

For the purpose of this section, the alternatives will be grouped into three main classes. The detailed assessment of the environmental impacts of each of the alternatives is contained in Section B of the appendix to this report.

One of the major impacts of dredging would be the removal of the extant benthos in addition to a maximum of 3 feet (1 m) of bottom sediments. Turbidity, sedimentation, and the environmental effects of these parameters would depend on the type of dredge used, turbidity control measures, and the time of year the dredging is performed.

Some recolonization of the dredged area and the relatively pollutant-free bottom should occur within several years. Care in dredging the project area would also minimize impacts on nearby benthos which must supply the bulk of recolonizers for the dredged bottom. Major disrupters in nearby benthos may slow or halt the rate of hoped for recolonization. Turbidity from the dredging would cause the migration of particulate and particle-associated pollutants from the area, possibly negating the project purpose if this transport is not controlled.

The location and construction of any disposal area or areas are also important factors in assessing the environmental impacts dredging would have. The disposal areas recommended in this report would be located in Bailey Bay. The construction of these areas would have nearly the same environmental impacts as dredging. Beneficial impacts would accrue from the siting in the bay as pollutants in the dredged material would not be placed outside this area to possibly contaminate other ecosystems. The amount of dredging would also be reduced if part of the Kepone-contaminated area is contained within the levees of the proposed disposal areas. The use of Bailey Creek as a disposal area would cause the loss of the habitat presently there. However, the filling and covering of this area may have the beneficial impact of sharply decreasing the input of pollutants to the semiaquatic and terrestrial ecosystems.

Truck hauling involved with the proposed dragline dredging operations may cause a short-term impact on air quality in the area by suspended particulate matter. A local elevation in noise levels may also be evident but will have little long-term effect. Social impacts would be limited to the effect of the disposal area on local esthetics.

The filling alternatives (3, 8, 15, 16, and 17) involve the covering or filling of part or all of the contaminated area with impervious cover material. As with the dredging, the implementation of these alternatives would remove potentially valuable estuarine habitat. Unlike dredging, the aquatic nature of much of the area covered would be lost due to the rise in elevation. Exact impacts due to the borrowing and transportation of materials would depend on the locations of the borrow areas, but some increase in noise and atmospheric and water-borne suspended particulate matter can be expected. Proper control measures would minimize both of these increases.

Although the habitat lost could not be replaced by the development of a "meadow type" habitat on the fill, a net environmental benefit may accrue if the area can be kept in a "pollutant free" state. This benefit would not accrue to these alternatives if the uptake of pollutants from the present ecosystems is minor.

Any social impacts that would occur during the actual covering operations would probably be acceptable to most people in the area if the areas are covered with topsoil and seeded.

Impoundments and dry dams with treatment plants were the final class of alternatives considered (alternatives 1, 2, 7, 12, and 14). The environmental impacts of these structures can vary widely depending on the management of water levels and wetlands in the dammed area. Cutting off the wetland areas from tidal influence would cause these areas to change from wetlands to upland-like habitat over time. The only way to prevent this would be to simulate tides in the areas dammed.

The treatment of outflows from the dams would prevent the continued input of pollutants from the Hopewell area to the James River. This treatment would also end the input of energy, in the form of organic carbon, to the James River system. The loss of this input may have a significant long-term effect on the James River system in this area.

Significant social impacts would result from the construction of the diversion dam and Chappell Creek outfall above the Route 156 bridge. Also the environmental impact of the diverted water on Chappell Creek would probably have significant long-term effects on this system.

Short-term impacts such as noise, a local increase in atmospheric particulates, and the introduction of sediment to the area waters during construction would occur.

More specifics on these impacts can be found in Section B of the appendix.

COMBINATION OF ALTERNATIVES

In the previous discussion, 18 separate alternatives for capturing, stabilizing, or removing Kepone in Gravelly Run, Bailey Creek, and/or Bailey Bay were described. Several of the alternatives considered all three critical areas under study. However, the majority of the alternatives address only one of the contaminated areas. For this reason, it is necessary to consider all reasonable alternative combinations for resolving the Kepone problem in Gravelly Run, Bailey Creek, and Bailey Bay together. After carefully examining the individual alternatives, 25 combined alternatives were found to be viable plans for protecting all three contaminated areas. Table 24 is a matrix showing the 25 plans and the individual alternatives composing each plan. It is important to note that when some of the alternatives were combined, certain design modifications were required. Specifically, alternatives 2, 7, and 13 are affected when combined with other alternatives. Alternative 2 would require constructing a dam at the mouth of Gravelly Run and diverting flow by gravity to Bailey Creek. However, when this alternative is combined with a dam at the mouth of Bailey Creek, a pumping station would be required to divert the water from Gravelly Run. Thus, the modified alternative is designated as Alternative 2A. Alternative 7 would require a dam at the mouth of Bailey Creek with a design crest elevation of 25 feet m.s.l. When it is combined with other alternatives, the required height of the dam varies depending on the drainage area controlled by the dam and the storage capacity required. Accordingly, alternatives denoted as 7A, 7B, 7C, 7D, 7E, 7F, and 7G represent different dam heights required for each particular plan involving Alternative 7. Finally, Alternative 13 would involve dredging all of Bailey Bay and pumping the material behind a dam on Bailey Creek. Since the optimum disposal site was determined to be site 14 occupying part of Bailey Bay, it was necessary to designate Alternative 13A for dredging part of Bailey Bay. Thus, whenever Alternative 13A is combined with other alternatives, it is also necessary to add the disposal area in Bailey Bay (site 14), as shown on the matrix.

Since each of the alternatives composing the 25 plans have already been described in detail, no detailed discussion of each plan was deemed necessary. Table 24 shows what alternatives were combined for each

Table 24. COMBINATIONS OF ALTERNATIVES CONSIDERED FOR DEVELOPING PLANS TO CAPTURE, STABILIZE, OR REMOVE KEPONE FROM GRAVELLY RUN, BAILEY CREEK, AND BAILEY BAY

Plan	1	2	2A	3	6	7	7A	7B	7C	7D	7E	7F	7G	8	11	12 [4]	13	13A	14	15	17	D.A.[1]
A	X					X												X				X
B	X						X										X					
C	X							X								X		X				X
D	X								X							X	X					
E	X													X				X				X
F	X														X			X				X
G			X							X								X				X
H			X								X						X					
I			X									X				X		X				X
J			X										X			X	X					
K				X		X												X				X
L				X			X										X					
M				X				X								X		X				X
N				X					X							X	X					
O				X										X				X				X
P				X											X			X				X
Q					X	X												X				X
R					X		X											X				X
S					X			X							X			X				X
T					X				X						X		X					
U					X									X				X				X
V					X										X			X				X
W																			X			
X [2]																				X		
Y [3]																					X	

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[1] D.A. - Disposal Area in Bailey Bay.
[2] Plan X is identical to Plan H.
[3] Plan Y is identical to Plan V.
[4] Alternative 12 utilizes gravity diversion.

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plan. In addition, table 25 summarizes the total first cost and annual costs, including operation and maintenance and major replacements of each plan as well as specific design modifications resulting from combining alternatives.

Table 25. SUMMARY OF COSTS OF PLANS FOR CAPTURING, STABILIZING, OR REMOVING KEPONE IN GRAVELLY RUN, BAILEY CREEK, AND BAILEY BAY

Plan	Individual Alternatives Involved	Total[1/] First Cost ($)	Annual Costs ($) Interest And Amortization	Major Replacement	Operation and Maintenance	Total	Remarks
A	1, 7, 13A, D.A.	21,955,000	1,457,000	-	447,000	1,904,000	
B	1, 7A, 13	17,955,000	1,192,000	-	115,000	1,307,000	Elevation of Dam 7A at mouth of Bailey Creek in 25.8 ft. m.s.l.
C	1, 7B, 12, 13, D.A.	40,773,000	2,705,000	-	636,000	3,341,000	Elevation of Dam 7B at mouth of Bailey Creek is 18.4 ft. m.s.l.
D	1, 7C, 12, 13	36,025,000	2,391,000	-	295,000	2,686,000	Elevation of Dam 7C at mouth of Bailey Creek is 19.8 ft. m.s.l.
E	1, 8, 13A, D.A.	33,628,000	2,232,000	-	564,000	2,796,000	
F	1, 11, 13A, D.A.	28,793,000	1,911,000	-	356,000	2,267,000	
G	2A, 7D, 13A, D.A.	29,133,000	1,933,000	7,000	519,000	2,459,000	Elevation of Dam 7D at mouth of Bailey Creek is 25.4 ft. m.s.l.
H	2A, 7E, 13	26,931,000	1,787,000	7,000	204,000	1,998,000	Elevation of Dam 7E at mouth of Bailey Creek is 26.5 ft. m.s.l.
I	2A, 7F, 12, 13A, D.A.	47,703,000	3,166,000	7,000	705,000	3,878,000	Elevation of Dam 7F at mouth of Bailey Creek is 19.0 ft. m.s.l.
J	2A, 7G, 12, 13	42,950,000	2,850,000	7,000	365,000	3,222,000	Elevation of Dam 7G at mouth of Bailey Creek is 20.1 ft. m.s.l.
K	3, 7, 13A, D.A.	22,218,000	1,474,000	-	450,000	1,924,000	
L	3, 7A, 13	18,218,000	1,209,000	-	117,000	1,326,000	Elevation of Dam 7A at mouth of Bailey Creek is 25.8 ft. m.s.l.
M	3, 7B, 12, 13A, D.A.	41,036,000	2,723,000	-	638,000	3,361,000	Elevation of Dam 7B at mouth of Bailey Creek is 18.4 ft. m.s.l.
N	3, 7C, 12, 13	36,288,000	2,408,000	-	298,000	2,706,000	Elevation of Dam 7C at mouth of Bailey Creek is 19.8 ft. m.s.l.
O	3, 8, 13A, D.A.	33,891,000	2,249,000	-	567,000	2,816,000	
P	3, 11, 13A, D.A.	29,056,000	1,928,000	-	358,000	2,286,000	
Q	6, 7, 3A, D.A.	21,720,000	1,441,000	-	435,000	1,876,000	
R	6, 7A, 13A, D.A.	22,748,000	1,510,000	-	445,000	1,955,000	Elevation of Dam 7A at mouth of Bailey Creek is 25.8 ft. m.s.l.
S	6, 7B, 11, 13A, D.A.	34,428,000	2,285,000	-	402,000	2,687,000	Elevation of Dam 7B at mouth of Bailey Creek is 18.4 ft. m.s.l.
T	6, 7C, 11, 13	29,680,000	1,970,000	-	62,000	2,032,000	Elevation of Dam 7C at mouth of Bailey Creek is 19.8 ft. m.s.l.
U	6, 8, 13A, D.A.	33,393,000	2,216,000	-	552,000	2,768,000	
V	6, 11, 13A, D.A.	28,558,000	1,895,000	-	343,000	2,238,000	
W	14	6,764,000	449,000	-	338,000	787,000	
X	15	26,931,000	1,787,000	7,000	204,000	1,988,000	
Y	17	28,558,000	1,895,000	-	343,000	2,238,000	

1/ Exclusive of cost of treatment facilities.

PART 3. DREDGING ANALYSIS OF THE JAMES RIVER

GENERAL

As an alternative for preventing the escape of Kepone from the James River, consideration has been given to dredging the entire river with selected disposal areas at given intervals within the river environment.

PLANNING OBJECTIVES

The planning objectives for this investigation were as follows:

a. The initial analysis was to consist of an overall estimate of the volume of dredged material resulting from dredging to an average depth of 15 inches from Hopewell, Virginia, to the mouth of the James River.

b. Determine if confined disposal of the dredged material is engineeringly feasible.

c. Provide an estimate of costs for dredging and disposal.

ENGINEERING CRITERIA

The following criteria were used in making the preliminary engineering analysis:

a. Excavation would be limited to the James River; therefore, no dredging was considered in tributaries of the James.

b. Excavation depth would be limited to 15 inches.

c. Disposal would be limited to confined overboard sites.

d. It was assumed that sand for disposal area construction would be within an economical pumping distance of each site.

e. It was assumed that the Oozer dredge would be available to dredge to a depth of 15 inches.

f. Approximately 25 percent excess material would be removed due to overdredging.

g. The Oozer pipeline would pump material 5,000 feet.

SITE DESCRIPTION

The James River flows 340 miles generally southeast from the Allegheny Mountains, entering Hampton Roads at Newport News, Virginia. The river is tidal from the mouth to Richmond, Virginia. At Hopewell, approximately 69 miles above the mouth (see plate 37), the width of the river is about 3,600 feet. The width of the river increases at the mouth to over 25,000 feet. As shown on plate 37, a 25-foot deep, 300-foot wide Federal navigation channel is maintained from the mouth to Richmond, Virginia. The pumping requirements of the dredging operation and the drainage from the river tributaries were considered when determining the location of the disposal areas. The disposal areas would be constructed with a spillway that is required in conjunction with the treatment facilities.

SUBSURFACE CONDITIONS

From a foundation standpoint, the subsurface conditions in the James River are believed to be extremely poor. The borings taken in Bailey Bay indicate organic deposits in depths up to 50 feet. These organic deposits are composed of peat, organic clays, and silts. Boring logs at the James River Bridge indicate that subsurface conditions throughout the study area are generally the same. Although subsurface conditions improve along the banks of the river in the vicinity of the bridge, the borings indicate that offshore organic deposits extend down to a depth of about 50 to 60 feet.

RECOMMENDED DESIGN

Plates 38 and 39 show the proposed 13 disposal areas for confinement of the dredged contaminated material. The sites selected are contiguous to the shore. Some drainage would be affected; however, if the material is strategically placed, the impact should be minimal. The levees would be constructed to a design height of 10 feet m.s.l. In order to allow for anticipated settlement and freeboard, the levee would be overbuilt initially by 5 feet. A typical section of the proposed levees is shown on plate 10. The levees would be constructed with hydraulic fill with an impervious bentonite and sand slurry cutoff trench and riprap protection on the outside levee slope. The hydraulic fill would be placed in two stages to prevent catastrophic shear failures. The first placement would constitute a working berm with a thickness of 7 feet above the mudline at the center axis of the levee with slopes of 1 vertical to 20 horizontal. The second stage would include placement of 10 feet of hydraulic fill with 1 vertical to 5 horizontal slopes. After placement of the second stage has been completed, the slopes would be reworked or shaped to 1 vertical to 3 horizontal. Filter cloth, bedding material, and riprap would then be placed on the outside levee slope for protection of the easily erodible hydraulic fill material. A 1-foot layer of gravel placed on the 20-foot wide levee crest is proposed for a working roadbed for equipment. To prevent seepage, a 3-foot wide slurry trench would be constructed to a depth of at least 10 feet below the bottom of the hydraulic fill. The slurry trench would be located on the inside levee slope and would run the entire length of the structure.

As previously stated, an emergency spillway would be necessary in conjunction with the treament facilities. The spillway would be identical to that discussed in the draft report.

Disposal areas 3, 4, and 6 through 10 have been sized based on the available area. It was assumed that the available excess capacity of these sites could serve as disposal for future maintenance dredging from the existing Federal navigation project. The remaining areas have been sized to accommodate only the Kepone contaminated material. The area sizes and final elevations of fill area as follows:

Table 26. ELEVATION AND SIZE OF DISPOSAL AREAS--JAMES RIVER

Disposal area	Acres	Elevation of fill (m.s.l.)
1	444	10.4 1/
2	560	10.3
3	248	7.1
4	411	8.9
5	276	8.4
6	767	6.7
7	736	5.4
8	987	7.4
9	533	9.3
10	872	7.5
11	1,572	10.4
12	1,635	9.2
13	725	8.4

1/ The elevation of Area 1 reflects material also removed from Gravelly Run and Bailey Creek.

Plates 38 and 39 also show the dredging areas in the James River apportioned to each disposal area. The following table shows the quantities to be dredged from each disposal area.

Table 27. QUANTITIES TO BE DREDGED FROM EACH DISPOSAL AREA--JAMES RIVER

Disposal area	Quantity (in 1,000 cubic yards) 15" Depth	Quantity (in 1,000 cubic yards) 25% Excess included
1	7,440	9,300
2	8,610	10,763
3	2,790	3,487
4	6,740	8,425
5	5,050	6,312
6	10,440	13,050
7	12,830	16,038
8	18,440	23,050
9	11,300	14,125
10	14,260	17,825
11	37,780	47,225
12	28,460	35,575
13	12,780	15,975
TOTAL	176,920	221,150
ROUNDED	177,000	221,000

POTENTIAL CONSTRUCTION PROBLEMS

The main operational problem would be to design the barge and Oozer pump to allow it to operate throughout the entire river system with sufficient depth to maintain the 15-inch cut.

It is anticipated that problems could arise during placement of hydraulic fill for the various disposal areas. Based on past experience with similar conditions, mud waves can develop in soft foundation conditions if the hydraulic fill is not properly baffled and spread with very flat slopes. Erosion from tidal action could also be a continuous problem until the riprap protection is completed.

In addition to the above problems, placement of the slurry trench may include difficulties in mobilization of the equipment on the levees and the excavation of the trench within the granular fill.

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COST

The following cost is a rough calculation based on Oozer production rates obtained from Seattle District, Corps of Engineers.

Dredging. Based on that data, it will take one Oozer dredge working by itself 120 years to complete the dredging. More realistically, 25 Oozer dredged aided by 45 booster pumps could complete the work in about 5 years. This latter number can probably be reduced, however, by optimum combinations of plants and dredging sites. The logistics of a job this size is awesome. The determination of the dredging time is based on many simplified assumptions and presented in the following table.

Table 28. DREDGING QUANITY AND COST--JAMES RIVER

Item		Cost
Mobilization and Demobilization		
70 plants @ $80,000 per plant	$ 5,600,000	
Miscellaneous	1,400,000	
177,000,000 c.y. @ $2.95 per c.y.	522,150,000	
		$529,150,000
Contingencies @ 20%		105,830,000
Subtotal, Dredging Cost		$634,980,000
Engineering and Design @12%		$ 76,198,000
Supervision and Administration @ 8%		50,798,000
TOTAL DREDGING COST		$761,976,000
ROUNDED		$762,000,000

Disposal Preparation. The disposal sites would be constructed similar to the existing Craney Island Disposal Area. They would be sealed in the same manner as that presented in Part 2 of this report. The estimate of cost for disposal is shown in the following table.

Table 29. COST OF DISPOSAL AREAS--JAMES RIVER

Disposal area	Cost
1	$ 3,550,000
2	4,480,000
3	7,610,000
4	11,990,000
5	11,850,000
6	9,200,000
7	15,110,000
8	15,340,000
9	13,950,000
10	11,620,000
11	17,380,000
12	20,200,000
13	10,840,000
	$153,120,000
Contingencies @ 20%	30,620,000
Subtotal, Disposal Areas	$183,740,000
Engineering and Design @12%	$ 22,050,000
Supervision and Administration @ 8%	14,700,000
TOTAL DISPOSAL AREA COSTS	$220,490,000
ROUNDED	$220,500,000

COST OF DREDGING JAMES RIVER

The results of this preliminary analysis present the magnitude of removing 177 million cubic yards of contaminated material from the James River at a cost of $982,500,000.

PART 4. CONCLUSIONS

Three important factors have been investigated in this report.

In Part 1 an investigation was made of world dredging technology and methods for reducing the resuspension of contaminated sediments in rivers and on the sea bottom. In view of the serious pollution problem in Japan and the recent development therein of equipment to minimize resuspension of secondary pollution, an on-site field inspection was made by a team composed of representatives from the Environmental Protection Agency and the Corps of Engineers. The team was impressed with the operation of the Oozer dredge and the stabilization of polluted sludge in situ in rivers and on the sea bottom by the sludge solidification system.

In Part 2 a number of alternatives were developed for controlling, stabilizing, or removing the Kepone-contaminated sediments from the Bailey Bay, Bailey Creek, and Gravelly Run areas. These included (1) dams and/or levees, (2) dredging, (3) covering the contaminated areas with soil or (4) combinations thereof. Although the Oozer would have been the preferred equivalent for estimating the cost of dredging, such a dredge was not available in this country, and at the time the studies for the Bailey Bay area were underway, detailed data thereon were not compiled. Accordingly the Mud Cat was used primarily to obtain an indication of the order of magnitude of the cost. Use of the Oozer would undoubtedly increase the cost due to the mobilization of this equipment from Japan and the demobilization thereof and its return to that country. However the Oozer delivers a greater density of dredged material with a lesser amount of water. Consequently the size of disposal area and amount of treatment capacity for the water effluent would be lessened.

Table 25 shows that the cost of the various alternatives considered for treating Kepone-contaminated sediments in Bailey Bay, Bailey Creek, and Gravelly Run ranged from about 7,000,000 to 48,000,000. It also shows the annual costs, including operation and maintenance and major replacements of each plan as well as specific design modifications, resulting from combining alternatives. Final screening or evaluation cannot be accomplished until all costs are known. The cost of treatment will most likely play an important part in plan selection or recommendation. The total first cost and annual charges shown in table 25 indicate that some of the plans that include dam construction are more cost effective than the dredging and covering plans. However, facilities required for treating runoff will undoubtedly be more costly than the treatment facilities required for dredging. After the cost for treatment is determined and a final estimate is complete, it may show that the plans including the construction of dams are not only less cost effective but may be the most costly.

From an environmental standpoint, if the Kepone input is eliminated from the Bailey Bay area, it would be a positive benefit to the James River system. On the otherhand, there is the potential for environmental damage to the project area and the James River ecosystem by the construction of some of the alternatives, as indicated in previous paragraphs. For example, significant social impacts were shown to be associated with alternative 12, the diversion of flow from upper Bailey Creek, combined with another alternative for solving the Kepone problem in the polluted portion below the existing sewage treatment plant. Furthermore, measures to control runoff would have devastating environmental effects on the nearly 400 acres of tidal marsh and swamp in the project area. The alternatives involving the covering of the contaminent area with soil would still impact on the wetland areas although for a relatively shorter time period than the construction of dams.

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Results recently determined by agencies other than the Corps of Engineers indicate that:

a. Plants in the project area have not accumulated Kepone in their stems or leaves. However, Kepone has been found associated with the root system of the plants. Other samples from the study area have indicated that Kepone may coat the surfaces of plants and thus be available for uptake to herbivorous insects and animals.

b. The amount of Kepone that is contained in the water column in Bailey Creek from fluvial runoff is diluted below the accepted allowable limits by the James River. Therefore, no treatment of overland runoff is required. This eliminates the need for the construction of dams to divert the flow from either Bailey Creek or Gravelly Run and the need to treat the runoff.

In Part 3, an estimate of cost is presented for dredging the Kepone-contaminated sediments in the 69 miles of James River from Hopewell to the mouth and placing it in 13 areas contiguous to the shore and covering it with soil. A 15-inch cut of the contaminated sediments would be accomplished with an Oozer dredge for which approximate costs were established based on a modification of the Penuma dredge that was recently used in the Duwamish Waterway by the Seattle District of the Corps of Engineers. The modification consisted of including a vacuum pump and other equipment as included in the Oozer to assist in the dredging operation.

Kepone-contaminated material (177 million cubic yards) would require removal by dredging at a cost of $982 million. The cost of treating the water effluent was not included.

Four methods have been described for alleviating the Kepone problem. These are the construction of dams and appurtenant structures, covering the contaminated area with soil, dredging and disposal, and soil solidification and fixation. This district favors the latter two methods.

Based on the following considerations and current information, it is this district's best judgment that use of the Oozer dredge should be given serious consideration for dredging of the James River if Kepone cleanup is undertaken.

a. Kepone's toxicity effects on marine organisms at very low concentrations.

b. The need to keep Kepone and other contaminant resuspension and stabilization to a minimum.

c. The James River bottom conditions of sandy, silty sediments and broad shallow areas adjacent to the channel.

d. Apparent inability of the U.S. dredging companies to handle large quantities of contaminated sediments.

e. The advanced technology of the Japanese dredging industry for contaminated sediments.

f. The investigation of the Environmental Protection Agency/Corps of Engineers team indicating that the Japanese Oozer and Clean-Up dredges are suited for removal of contaminated sediments. Information indicates that the Clean-Up dredge has experienced some operational difficulties over the Oozer dredge. This suggests that the Oozer dredge would be the best choice for the James River project.

g. The Oozer dredge's minimal operational difficulties and adaptability of the small Oozer dredge for movement to the United States for onsite evaluation.

i. The Oozer dredge's capability to remove contaminated material with minimal bottom sediment disturbance while dredging.

j. The Oozer's ability to dredge material at or near in-place density thus minimizing spoil site size and costs, elutriate treatment costs, and hazards of recontamination.

k. The Oozer's adaptability to dredging in both shallow and deep areas.

It would be advantageous to simultaneously and thoroughly test the Oozer's operating, production, and secondary pollution abatement efficiencies against that of all other dredges. Unfortunately, there are no known one-to-one comparisons. Furthermore, it is unlikely that such comprehensive comparisons will be made in the near future. Any comparisons on a production basis would need to consider the total system of dredging and disposal. For example, conventional dredges produce greater volume but lower concentration rates. Lower solids concentration in the volumes dredged means that greater treatment and disposal costs will be incurred during handling of contaminated material.

A prudent and feasible alternative is suggested in view of the immense costs and high improbability of a large scale side-by-side investigation of all dredges for application to the specific problem in the James River. The small Oozer dredge can be easily dismantled and the essential parts transported to the United States for a test project. The test project would be designed with the assistance of the Dredging

Operations Technical Support program of the Corps of Engineers Waterways Experiment Station, the Norfolk District, Corps of Engineers, Environmental Protection Agency, and State of Virginia and Maryland representatives. Operating parameters could then be established on a site specific basis. These parameters could then be used to establish guidelines for dredging in the James River and evaluating other worldwide potential competing systems.

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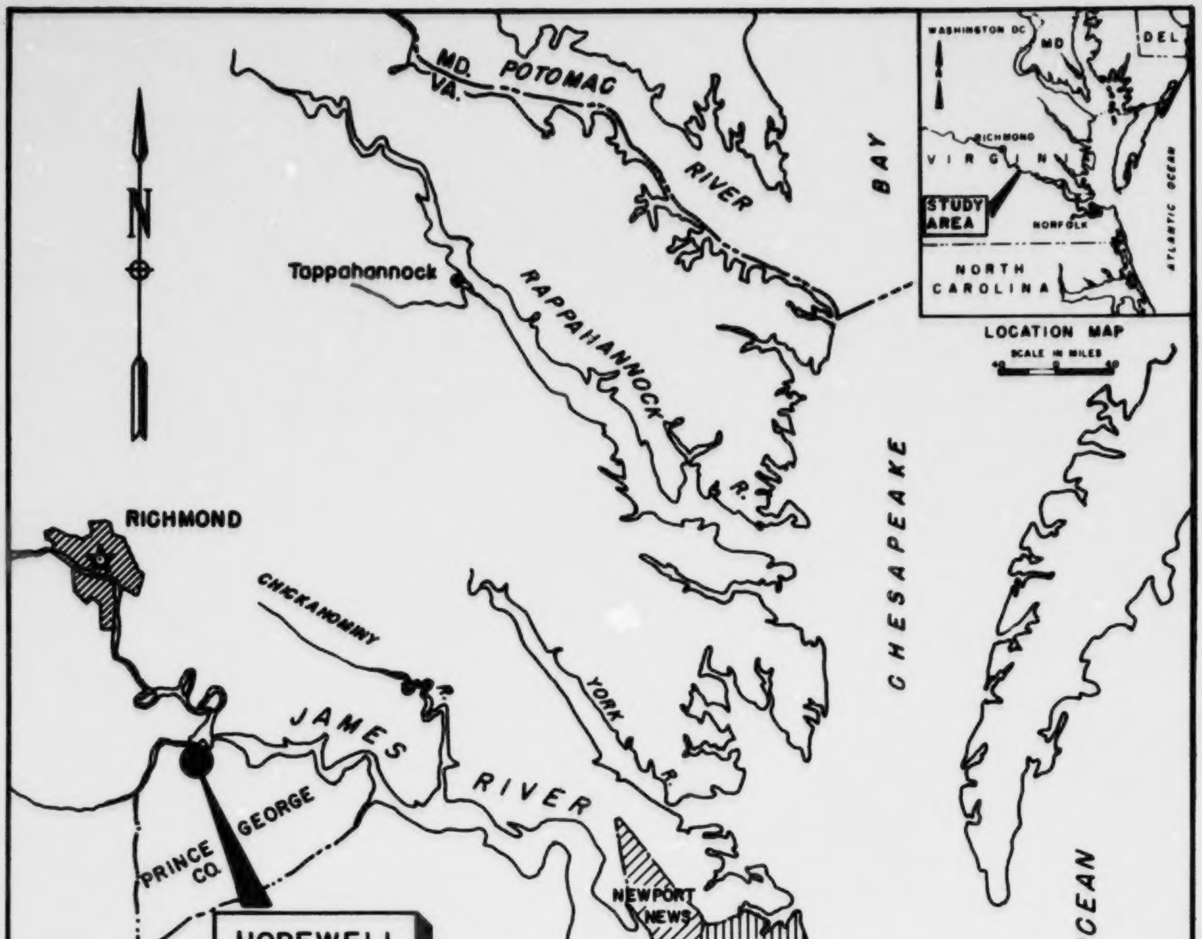
PART 5. RECOMMENDATIONS

It is recommended that serious consideration be given toward establishing a demonstration program in Bailey Bay to determine the feasibility of reducing the Kepone problem in the James River. It would involve the following:

a. The small oozer.

b. The Takenaka Sludge Treatment System if Takenaka Komuten Company can develop an appropriate binder that would fix the Kepone to the river bottom sediments.

c. The investigations to accumulate detailed data during actual dredging operations in other ports of the country, for other specific dredging equipment that attempts to reduce secondary pollution.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PORTSMOUTH
VIRGINIA
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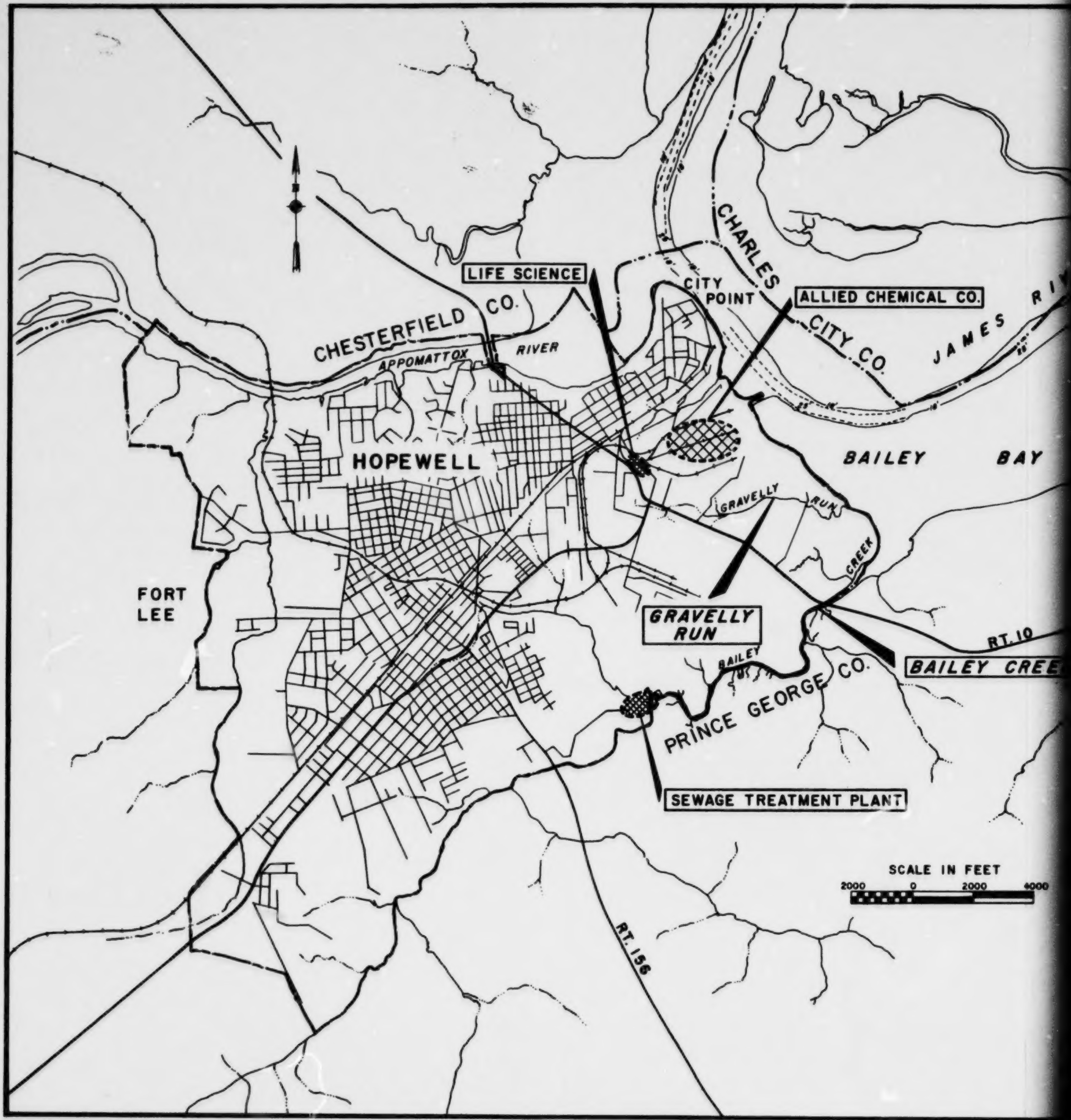
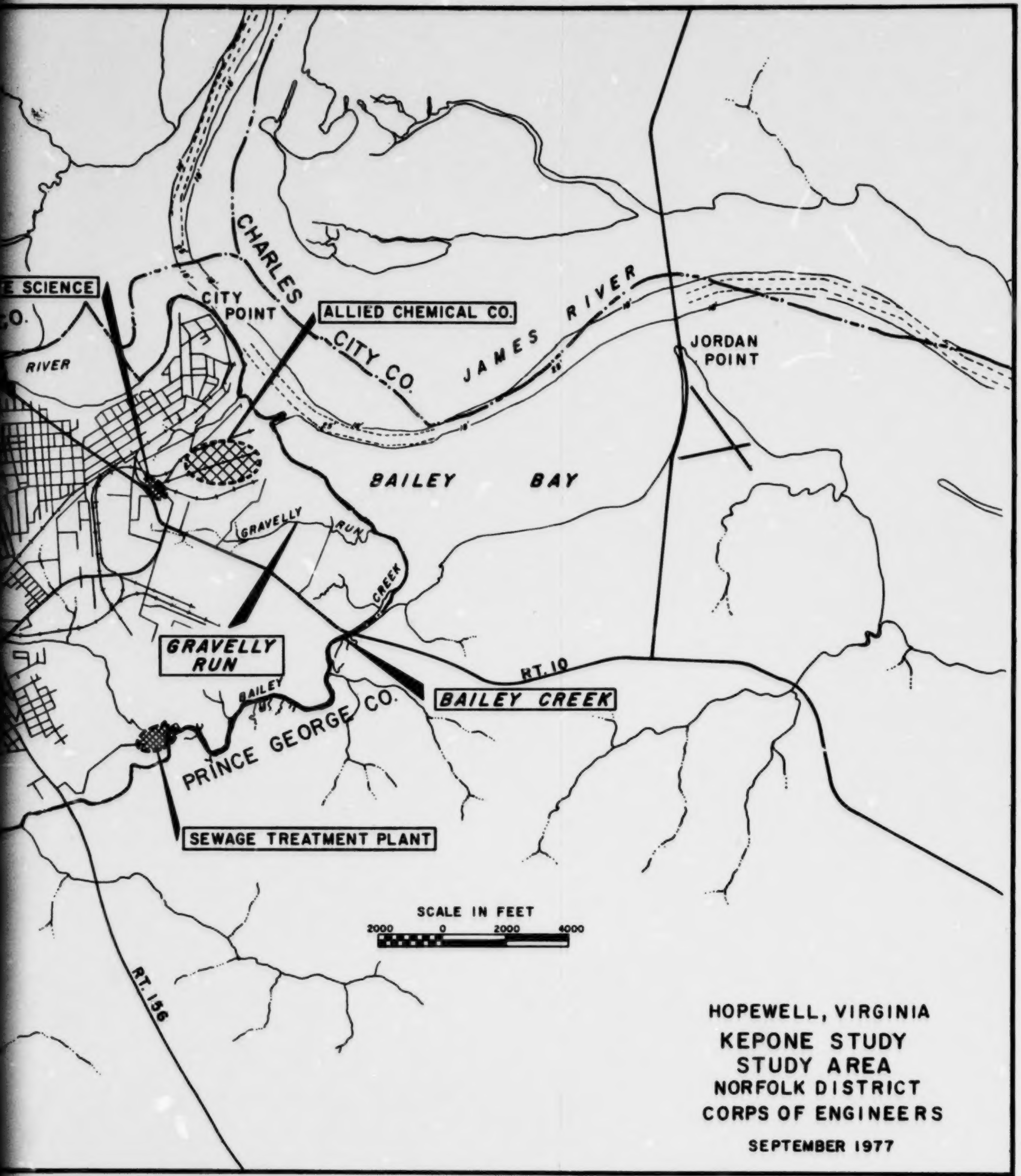
VIRGINIA
STUDY
AREA
NORFOLK
NORTH
CAROLINA
ATLANTIC OCEAN
LOCATION MAP
SCALE IN MILES
SCALE IN MILES
10
0
10
20
30
40

HOPEWELL, VIRGINIA
KEPONE STUDY
VICINITY MAP
NORFOLK DISTRICT
CORPS OF ENGINEERS
SEPTEMBER 1977


LIFE SCIENCE
CHESTERFIELD CO.
APPOMATTOX
RIVER
CITY POINT
CHARLES CITY CO.
ALLIED CHEMICAL CO.
JAMES RI
HOPEWELL
BAILEY BAY
GRAVELLY RUN
CREEK
GRAVELLY RUN
FORT LEE
RT. 10
BAILEY CREE
BAILEY
PRINCE GEORGE CO.
SEWAGE TREATMENT PLANT
SCALE IN FEET
2000 0 2000 4000
RT. 156

A

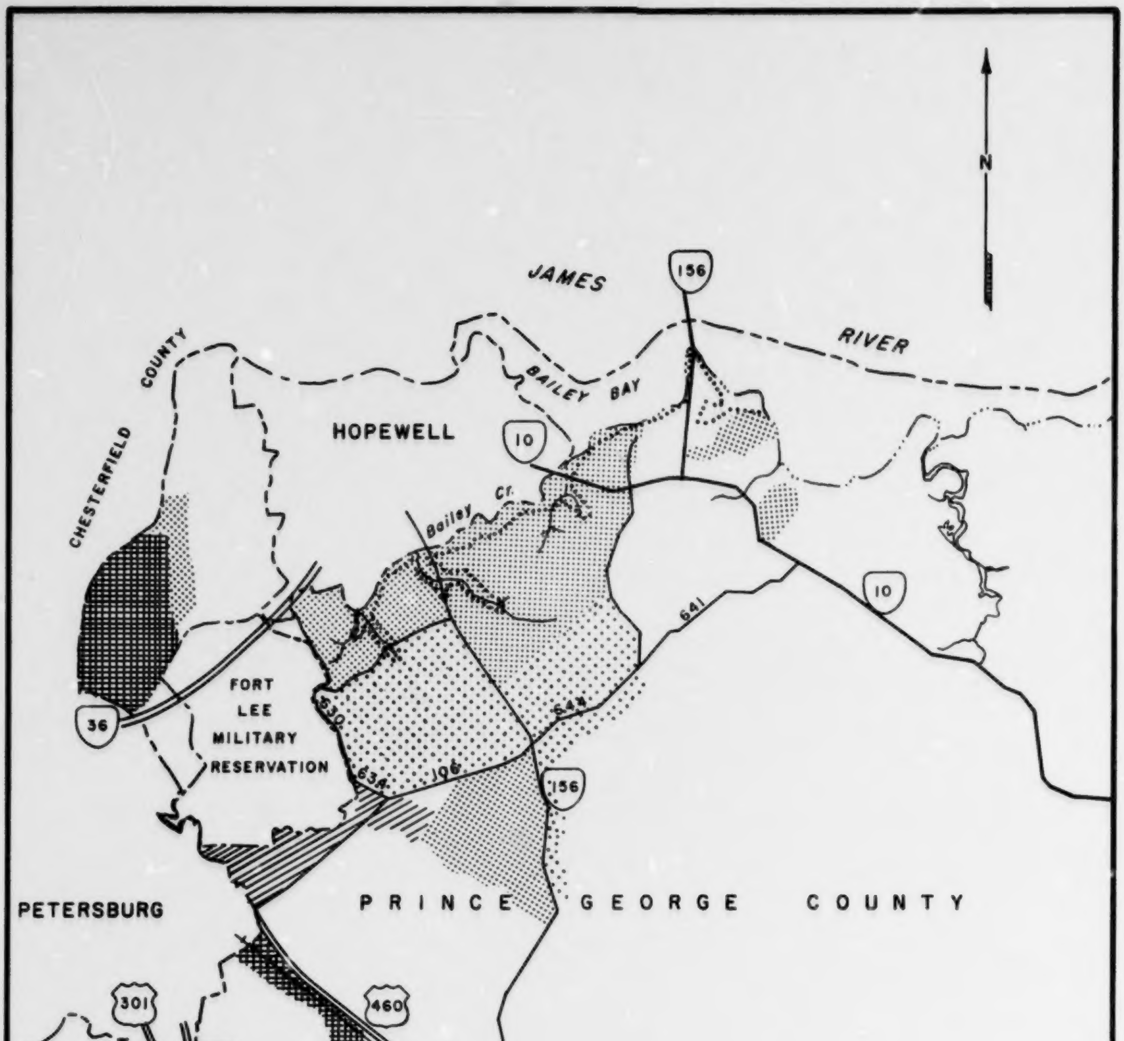

E SCIENCE
CITY POINT
ALLIED CHEMICAL CO.
CHARLES CITY CO.
JAMES RIVER
JORDAN POINT
RIVER
BAILEY BAY
GRAVELLY RUN
CREEK
GRAVELLY RUN
BAILEY CREEK
RT. 10
BAILEY
PRINCE GEORGE CO.
SEWAGE TREATMENT PLANT
SCALE IN FEET
2000
0
2000
4000
RT. 156

HOPEWELL, VIRGINIA
KEPONE STUDY
STUDY AREA
NORFOLK DISTRICT
CORPS OF ENGINEERS
SEPTEMBER 1977

PLATE 2

125<

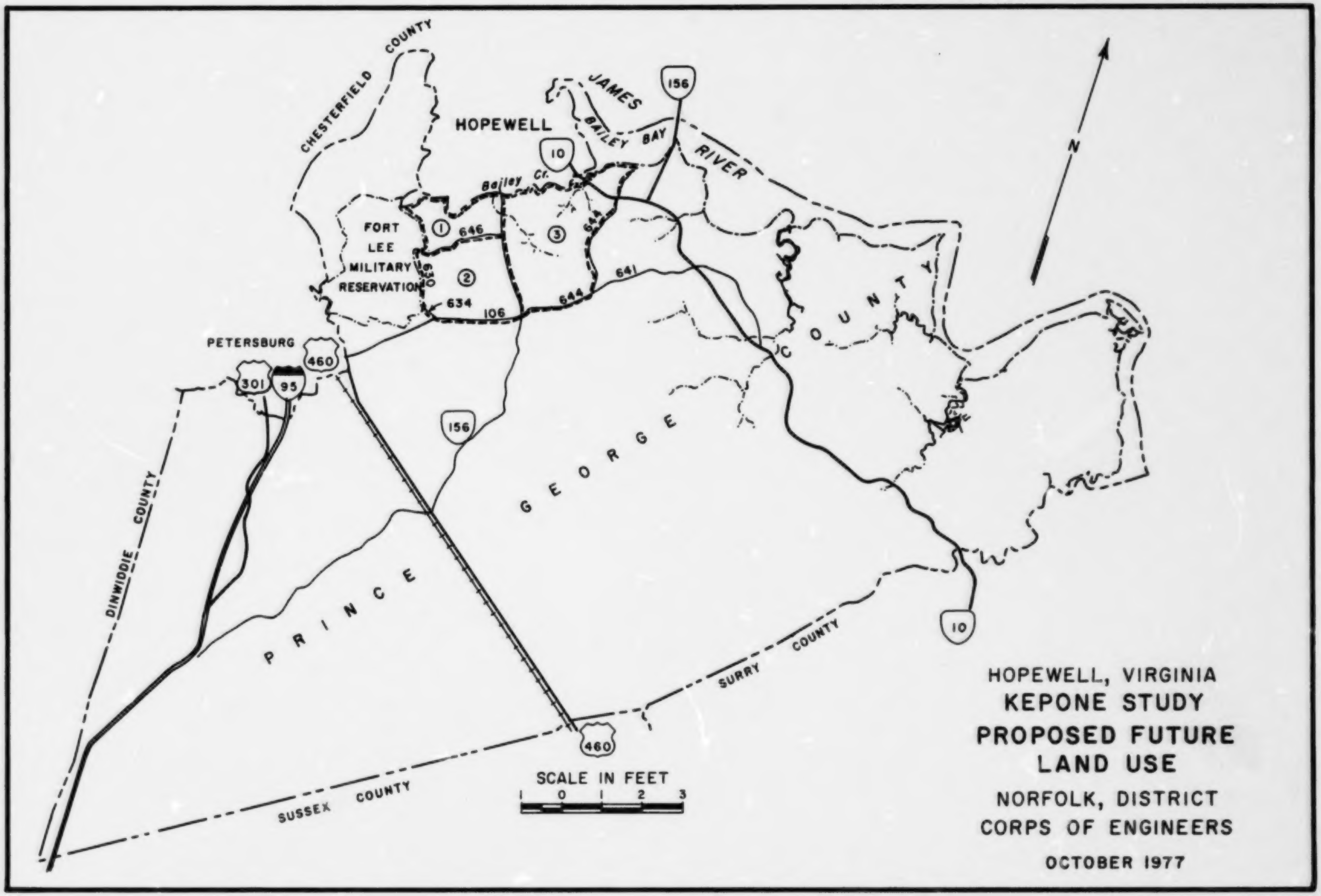
β


N
JAMES
RIVER
156
CHESTERFIELD COUNTY
BAILEY BAY
HOPEWELL
10
Bailey Cr.
641
10
FORT LEE MILITARY RESERVATION
36
630
634
106
644
156
PETERSBURG
PRINCE GEORGE COUNTY
301
460
95
SCALE IN MILES
1 0 1 2 3
LEGEND
SUBURBAN DEVELOPMENT -LOW DENSITY
SUBURBAN DEVELOPMENT -MEDIUM DENSITY 1
SUBURBAN DEVELOPMENT -MEDIUM DENSITY 2
INDUSTRIAL
CRITICAL ENVIRONMENTAL AREA

HOPEWELL, VIRGINIA
KEPONE STUDY
PROPOSED FUTURE LAND USE
NORFOLK, DISTRICT
CORPS OF ENGINEERS
OCTOBER 1977

126

PLATE 3


CHESTERFIELD COUNTY
HOPEWELL
JAMES
BAILEY BAY
RIVER
156
10
Bailey Cr.
FORT LEE MILITARY RESERVATION
①
②
③
646
630
634
106
644
641
N
COUNTY
PETERSBURG
460
301
95
156
DINWIDDIE COUNTY
PRINCE GEORGE
SURRY COUNTY
SUSSEX COUNTY
10
460
SCALE IN FEET
1 0 1 2 3

HOPEWELL, VIRGINIA

KEPONE STUDY

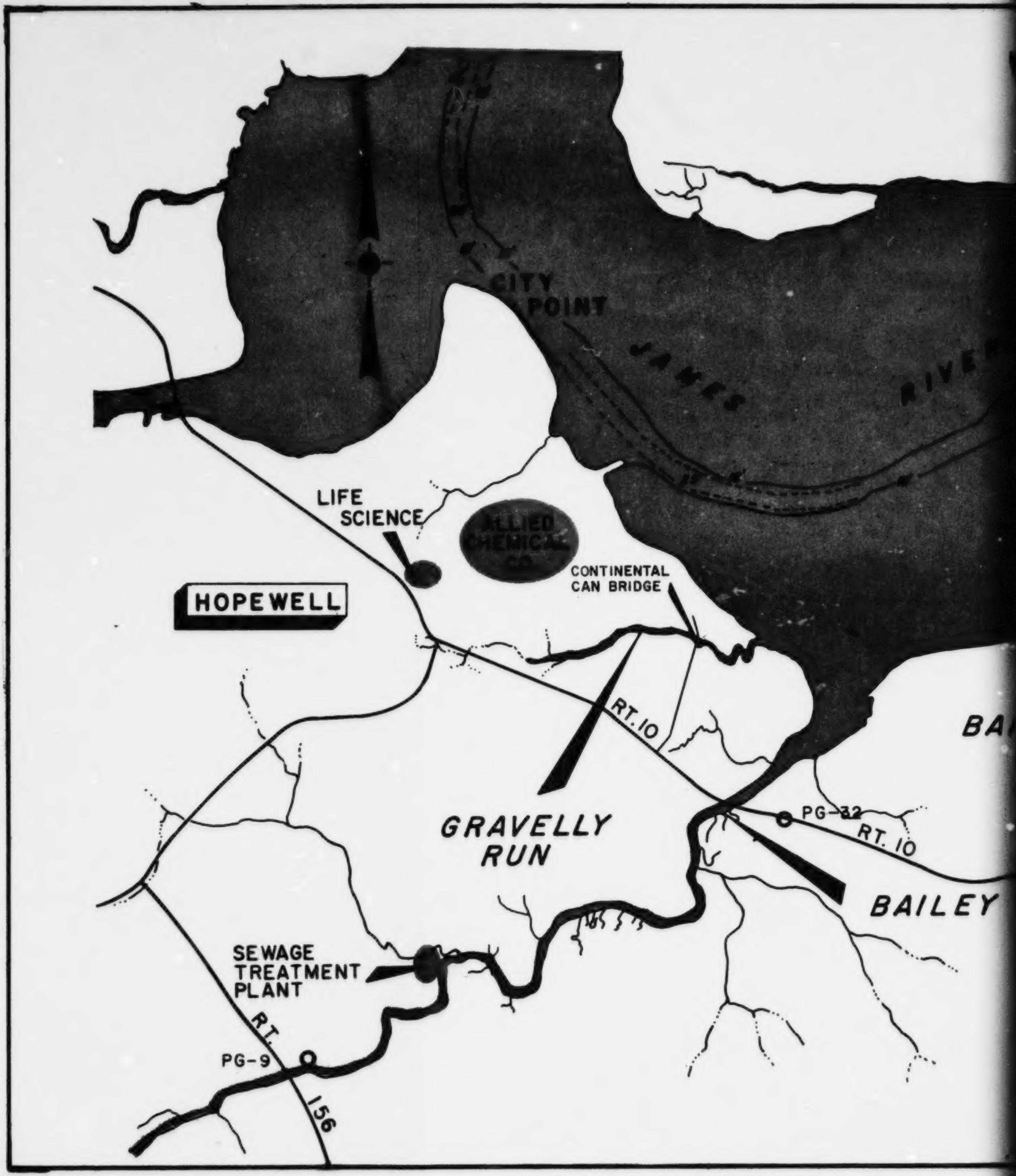
PROPOSED FUTURE LAND USE

NORFOLK, DISTRICT
CORPS OF ENGINEERS

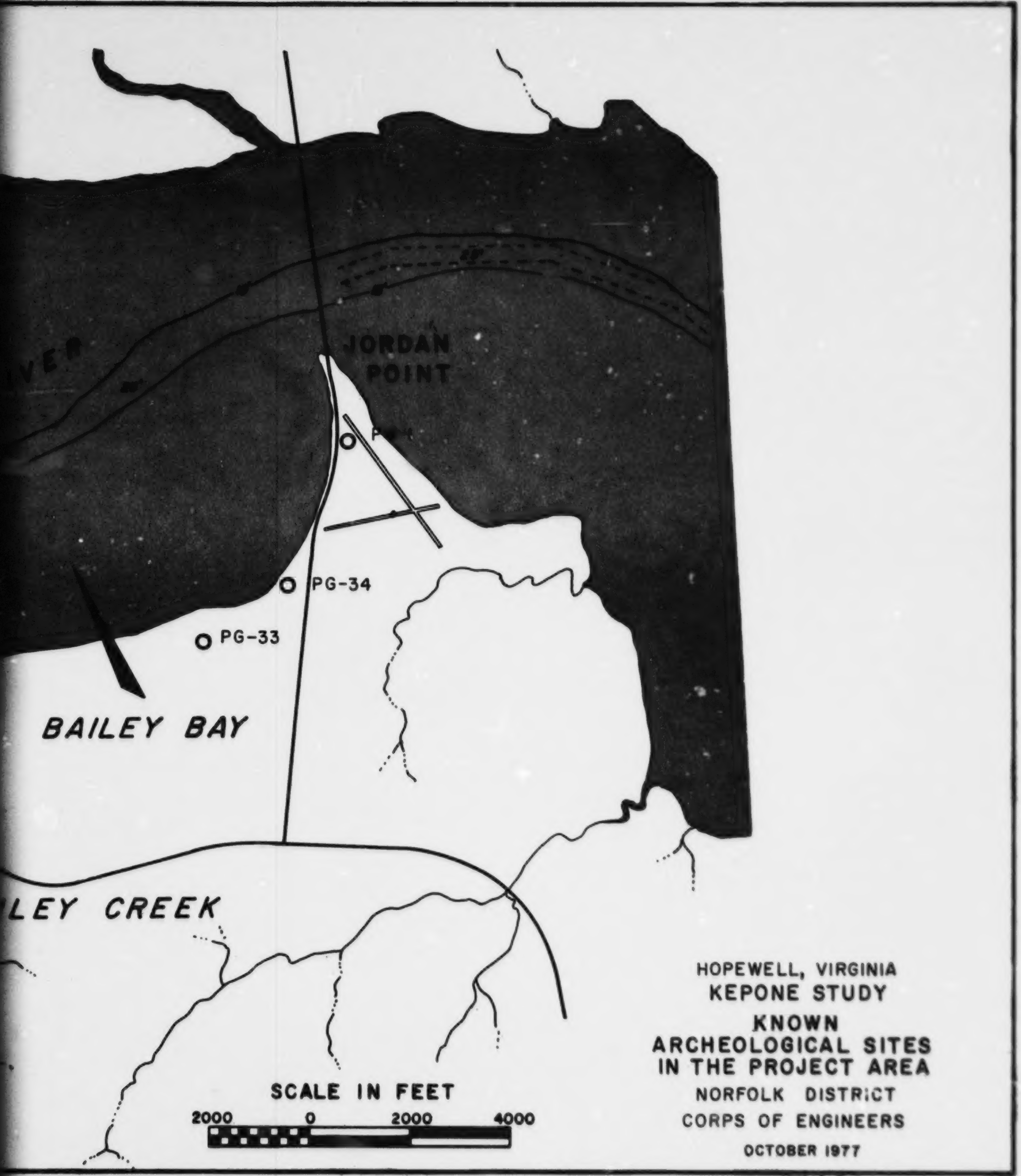
OCTOBER 1977

127<

PLATE 4


CITY POINT
JAMES
RIVER
LIFE SCIENCE
ALLIED CHEMICAL CO.
CONTINENTAL CAN BRIDGE
HOPEWELL
RT. 10
BA
GRAVELLY RUN
PG-32
RT. 10
BAILEY
SEWAGE TREATMENT PLANT
RT. 156
PG-9

A


IVER
JORDAN POINT
PG-34
PG-33
BAILEY BAY
LEY CREEK
SCALE IN FEET
2000
0
2000
4000

HOPEWELL, VIRGINIA

KEPONE STUDY

KNOWN ARCHEOLOGICAL SITES IN THE PROJECT AREA

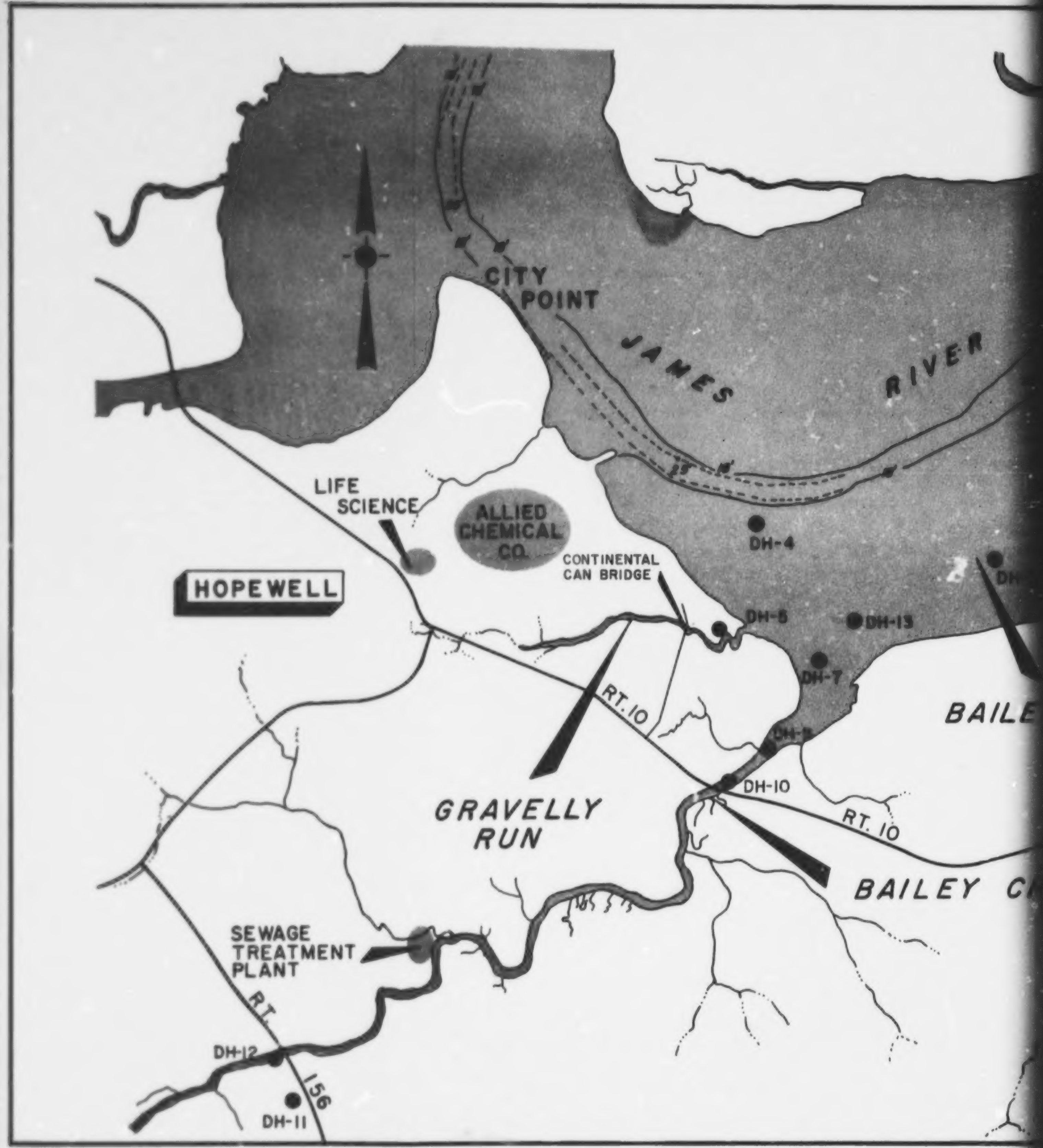
NORFOLK DISTRICT

CORPS OF ENGINEERS

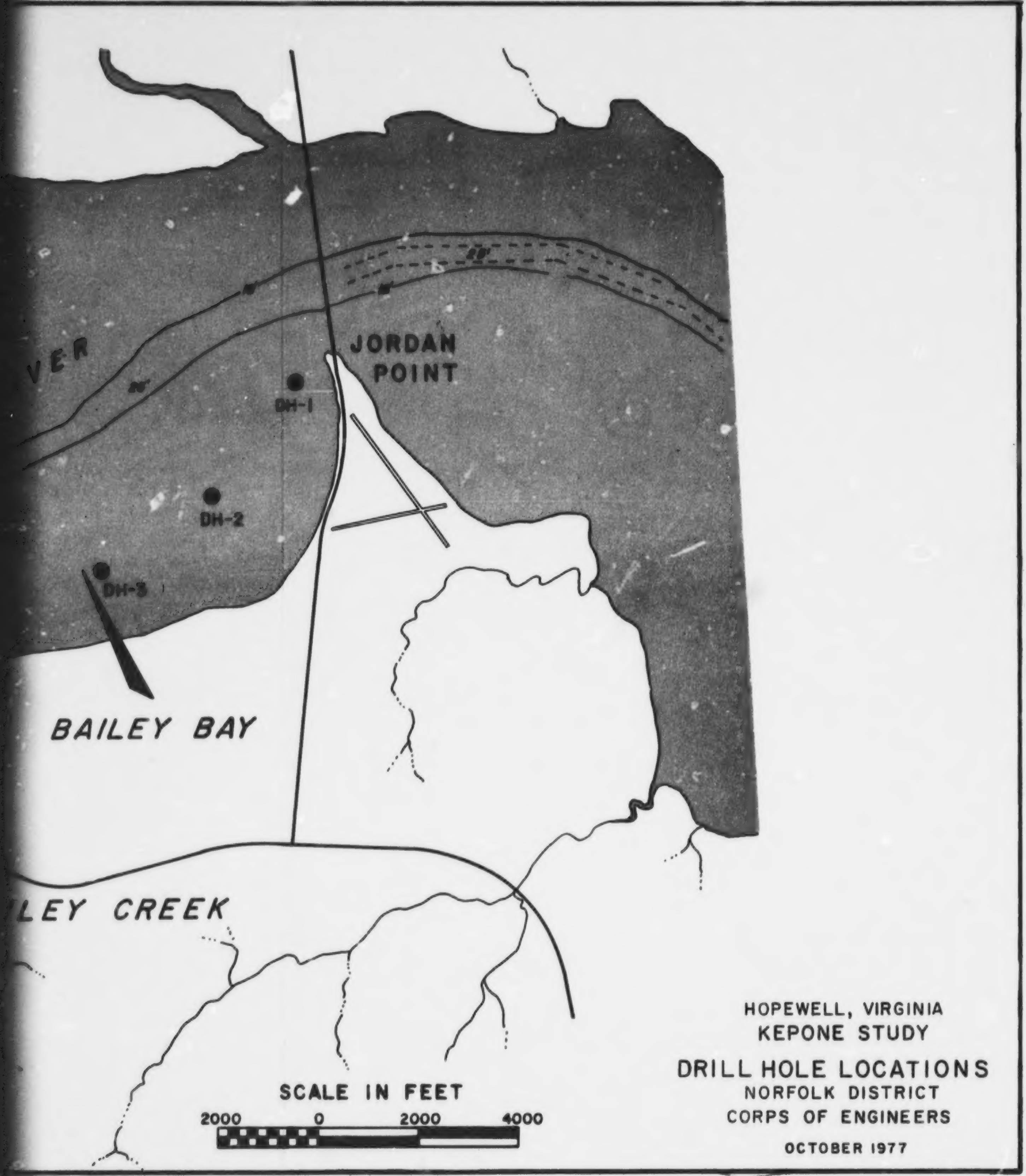
OCTOBER 1977

128<

PLATE 5 B


CITY POINT
JAMES RIVER
LIFE SCIENCE
ALLIED CHEMICAL CO.
HOPEWELL
CONTINENTAL CAN BRIDGE
DH-4
DH
DH-5
DH-13
DH-7
BAILE
RT. 10
DH-
DH-10
RT. 10
GRAVELLY RUN
BAILEY C
SEWAGE TREATMENT PLANT
RT. 156
DH-12
DH-11

P


VER
JORDAN POINT
DH-1
DH-2
DH-3
BAILEY BAY
ILEY CREEK
SCALE IN FEET
2000
0
2000
4000

HOPEWELL, VIRGINIA
KEPONE STUDY

DRILL HOLE LOCATIONS

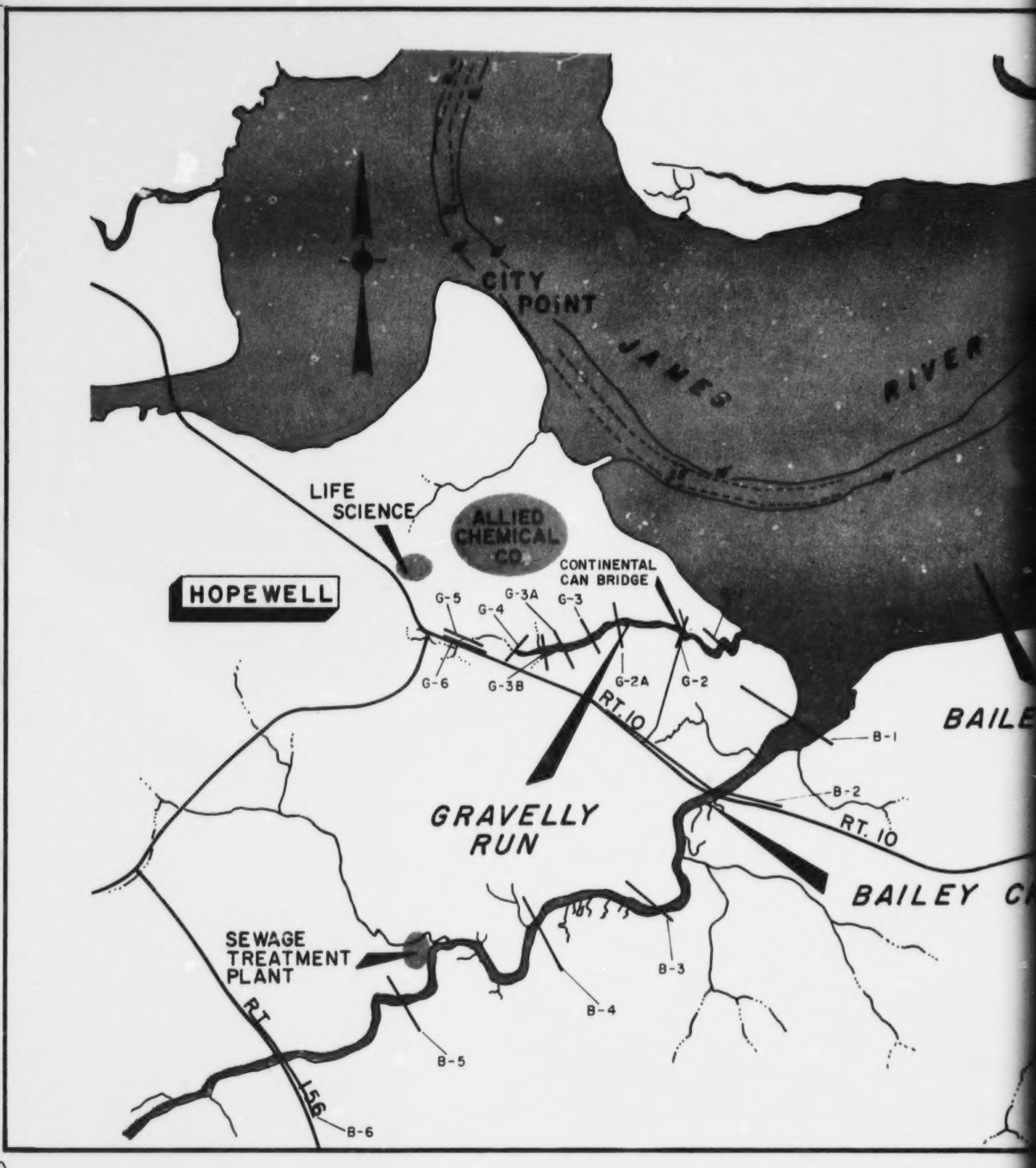
NORFOLK DISTRICT
CORPS OF ENGINEERS

OCTOBER 1977

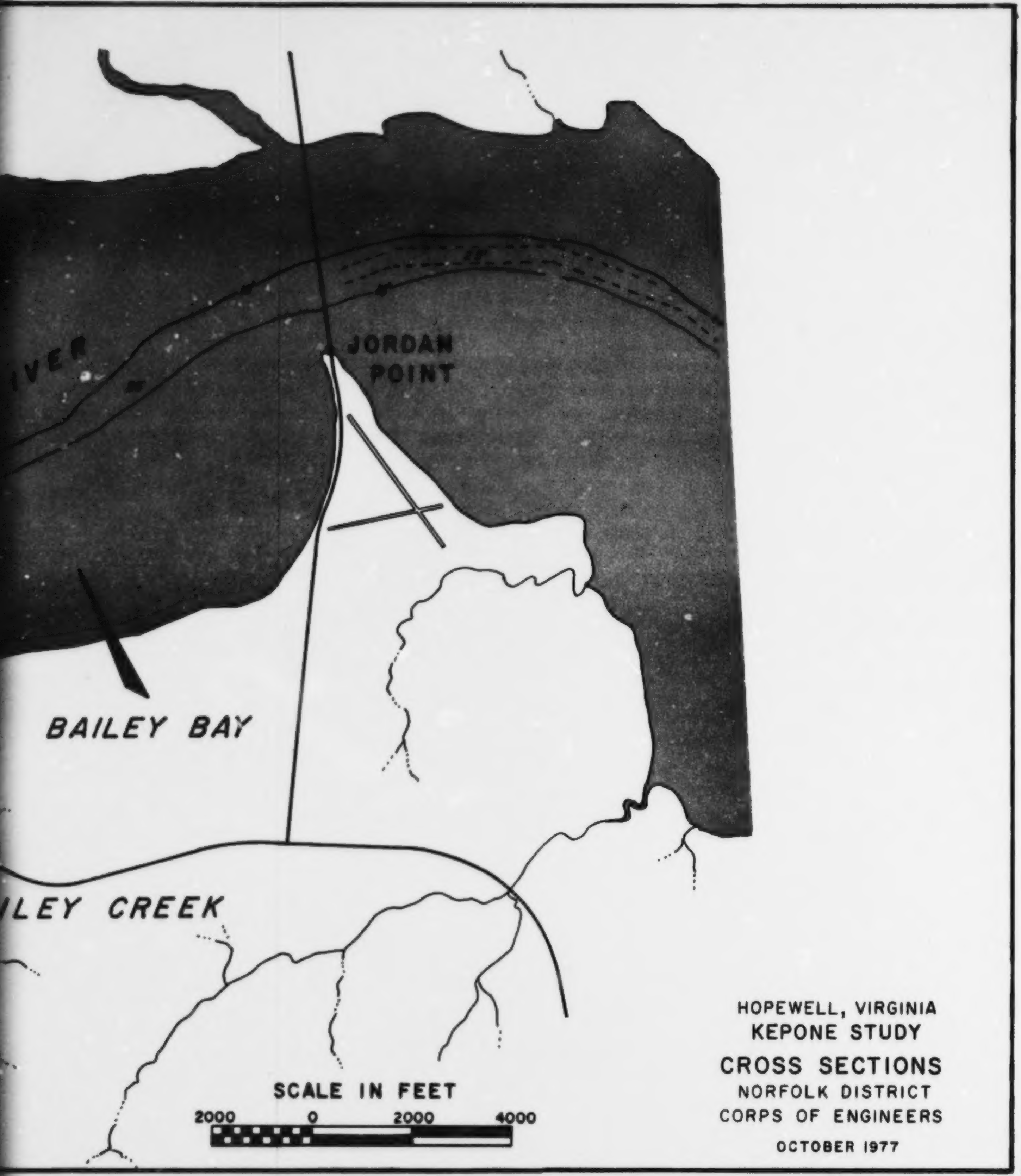
B

129<

PLATE 6


CITY POINT
JAMES RIVER
LIFE SCIENCE
ALLIED CHEMICAL CO.
CONTINENTAL CAN BRIDGE
HOPEWELL
G-5
G-4
G-3A
G-3
G-6
G-3B
G-2A
G-2
RT. 10
B-1
BAILE
B-2
RT. 10
GRAVELLY RUN
BAILEY C
B-3
SEWAGE TREATMENT PLANT
B-4
B-5
RT 156
B-6

A


IVER
JORDAN POINT
BAILEY BAY
ILEY CREEK
SCALE IN FEET
2000
0
2000
4000

HOPEWELL, VIRGINIA
KEPONE STUDY

CROSS SECTIONS

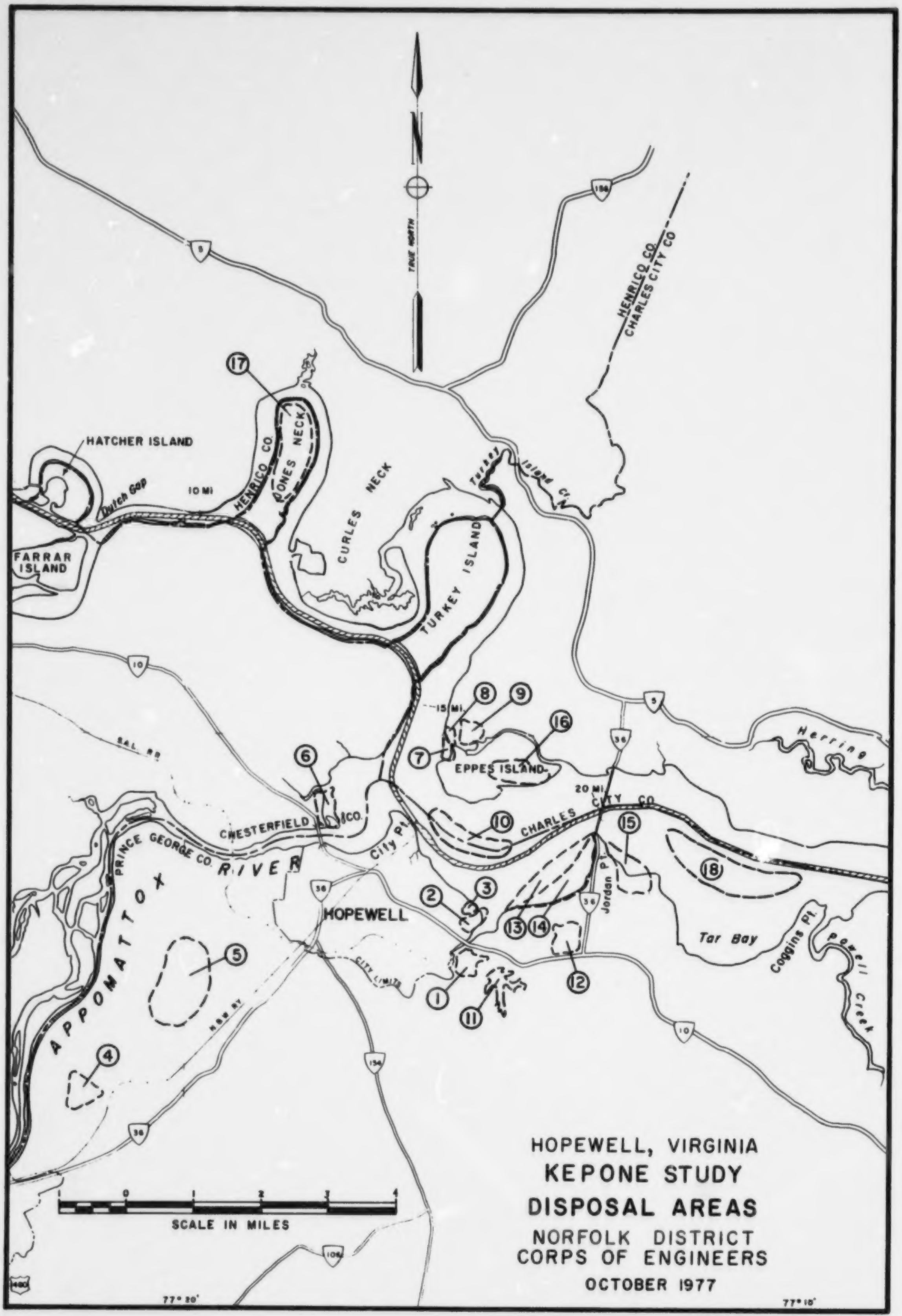
NORFOLK DISTRICT
CORPS OF ENGINEERS

OCTOBER 1977

B

130<

PLATE 7


TRUE NORTH
N
5
156
HENRICO CO.
CHARLES CITY CO.
17
HATCHER ISLAND
Dutch Gap
10 MI
HENRICO CO.
JONES NECK
CURLES NECK
Turkey Island Cr.
FARRAR ISLAND
TURKEY ISLAND
10
15 MI
8
9
16
7
EPPES ISLAND
5
36
Herring
SAL RR
6
20 MI
CHESTERFIELD CO.
CHARLES CITY CO.
10
15
PRINCE GEORGE CO.
RIVER
City Pt.
18
2
3
APPOMATTOX
36
HOPEWELL
13
14
36
Jordan Pt.
Tar Bay
Coggins Pt.
Powell Creek
5
12
CITY LIMITS
1
11
N&W RY
10
4
156
36
1
0
1
2
3
4
SCALE IN MILES
106
460
77° 20'
77° 10'

HOPEWELL, VIRGINIA

KEPONE STUDY

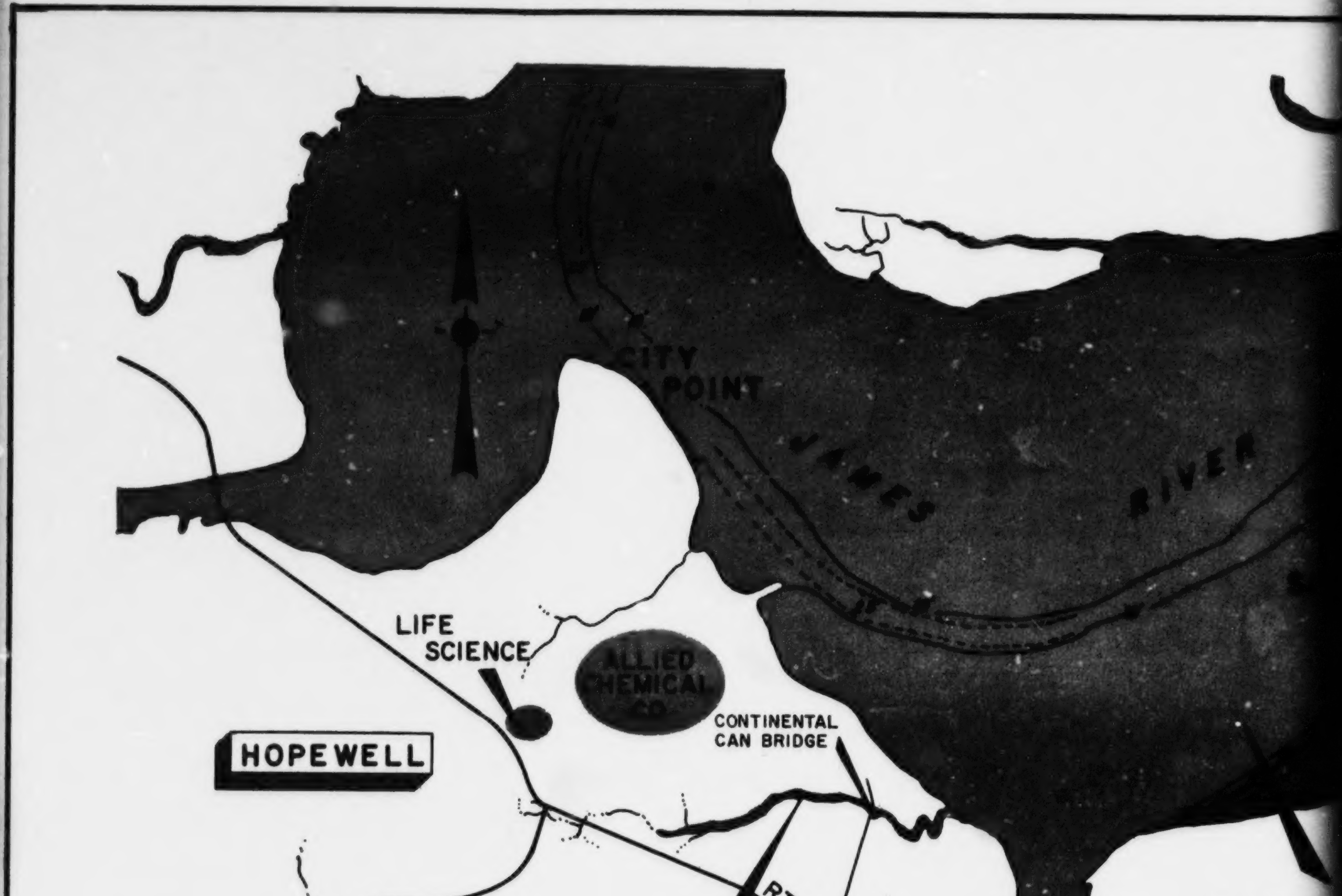
DISPOSAL AREAS

NORFOLK DISTRICT
CORPS OF ENGINEERS

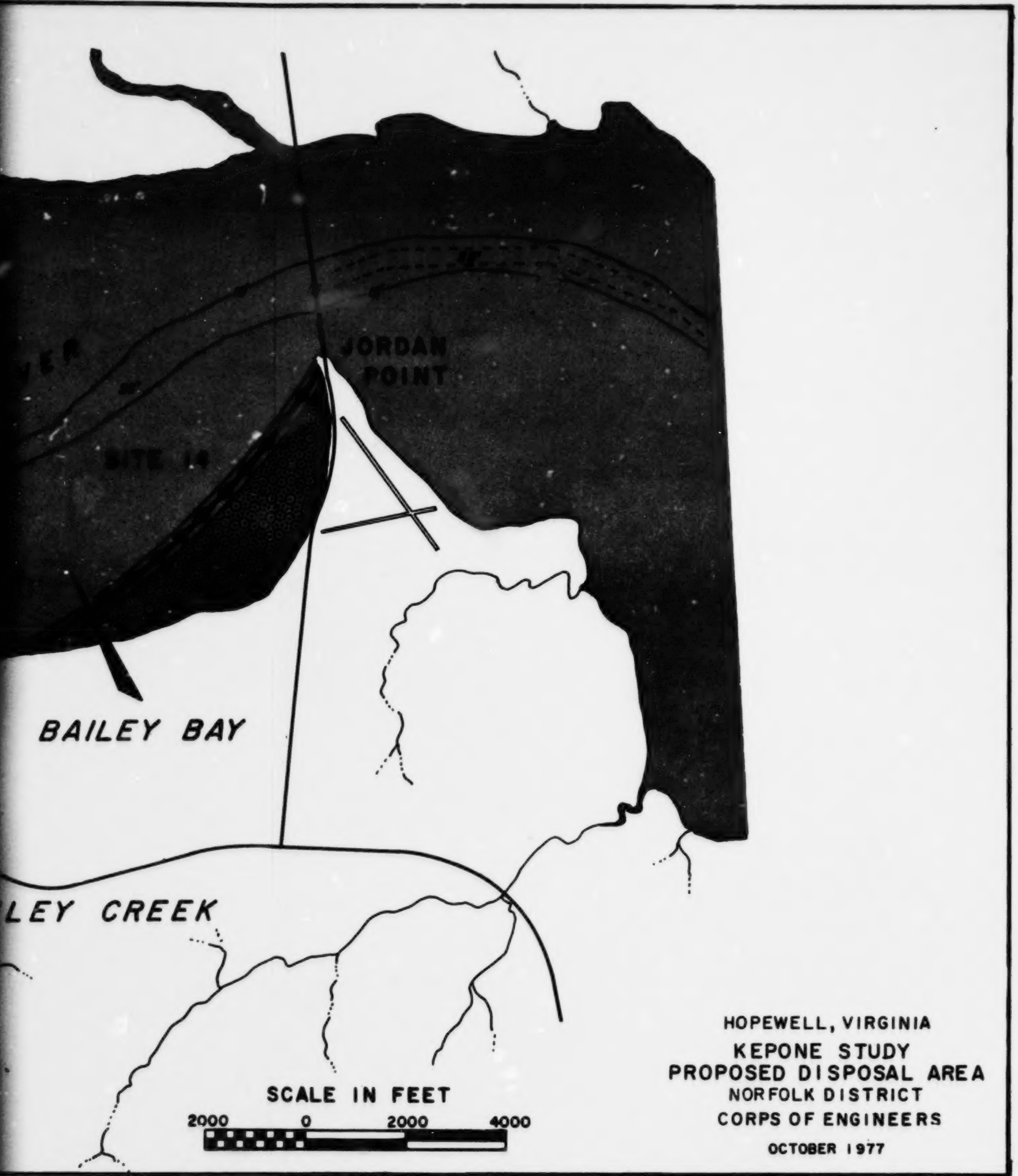
OCTOBER 1977

131<

PLATE 8


CITY POINT
JAMES RIVER
LIFE SCIENCE
ALLIED CHEMICAL CO.
CONTINENTAL CAN BRIDGE
HOPEWELL
RT. 10
GRAVELLY RUN
RT. 10
BAILE
BAILEY CR
SEWAGE TREATMENT PLANT
RT. 156

A


VER
JORDAN POINT
SITE 14
BAILEY BAY
LEY CREEK
SCALE IN FEET
2000
0
2000
4000

HOPEWELL, VIRGINIA

KEPONE STUDY

PROPOSED DISPOSAL AREA

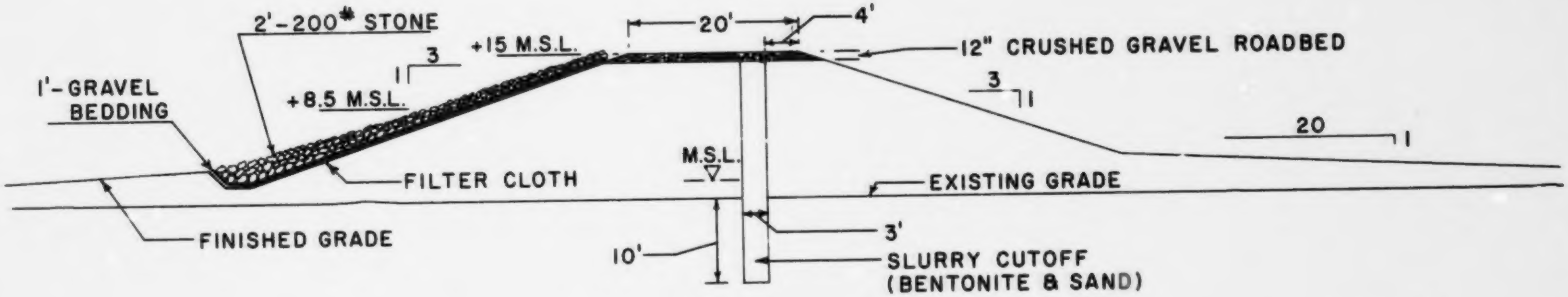
NORFOLK DISTRICT

CORPS OF ENGINEERS

OCTOBER 1977

B

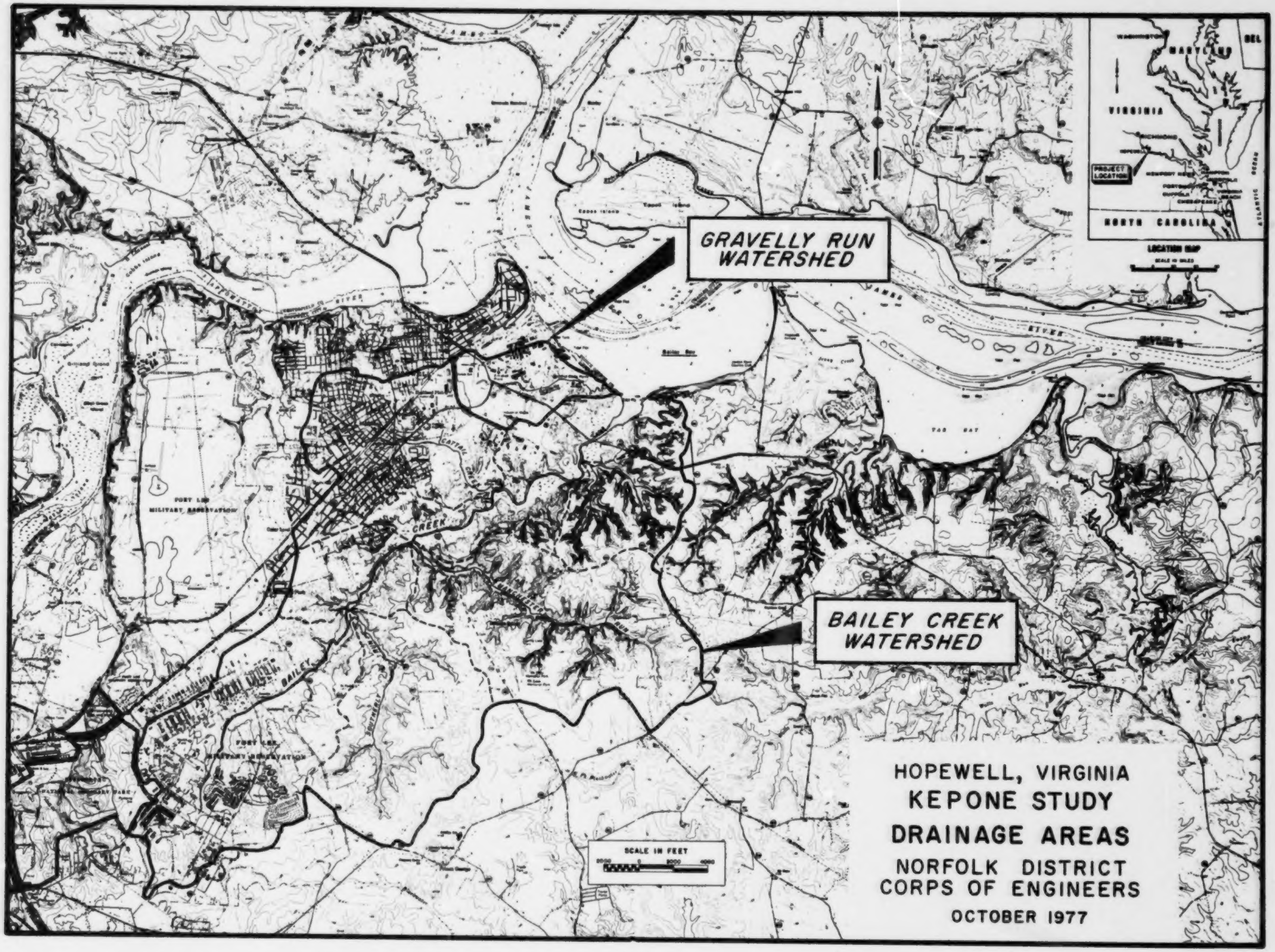
PLATE 9


2'-200# STONE
+15 M.S.L.
3
1
20'
4'
12" CRUSHED GRAVEL ROADBED
1'-GRAVEL BEDDING
+8.5 M.S.L.
3
1
20
1
M.S.L.
FILTER CLOTH
EXISTING GRADE
FINISHED GRADE
3'
10'
SLURRY CUTOFF (BENTONITE & SAND)

LEVEE

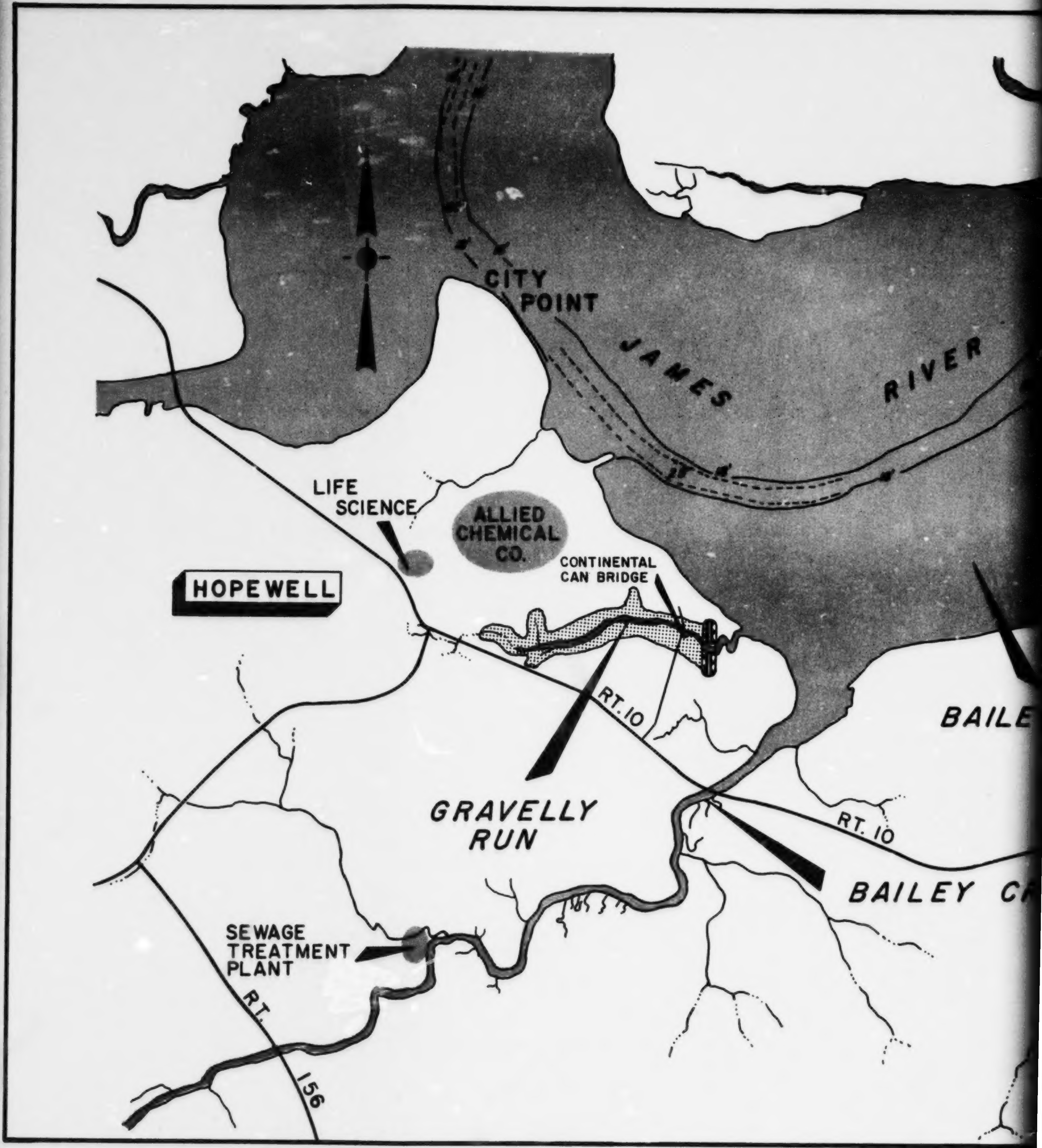
HOPEWELL, VIRGINIA
KEPONE STUDY
DISPOSAL AREA
TYPICAL SECTION
NORFOLK DISTRICT
CORPS OF ENGINEERS
OCTOBER 1977

PLATE 10

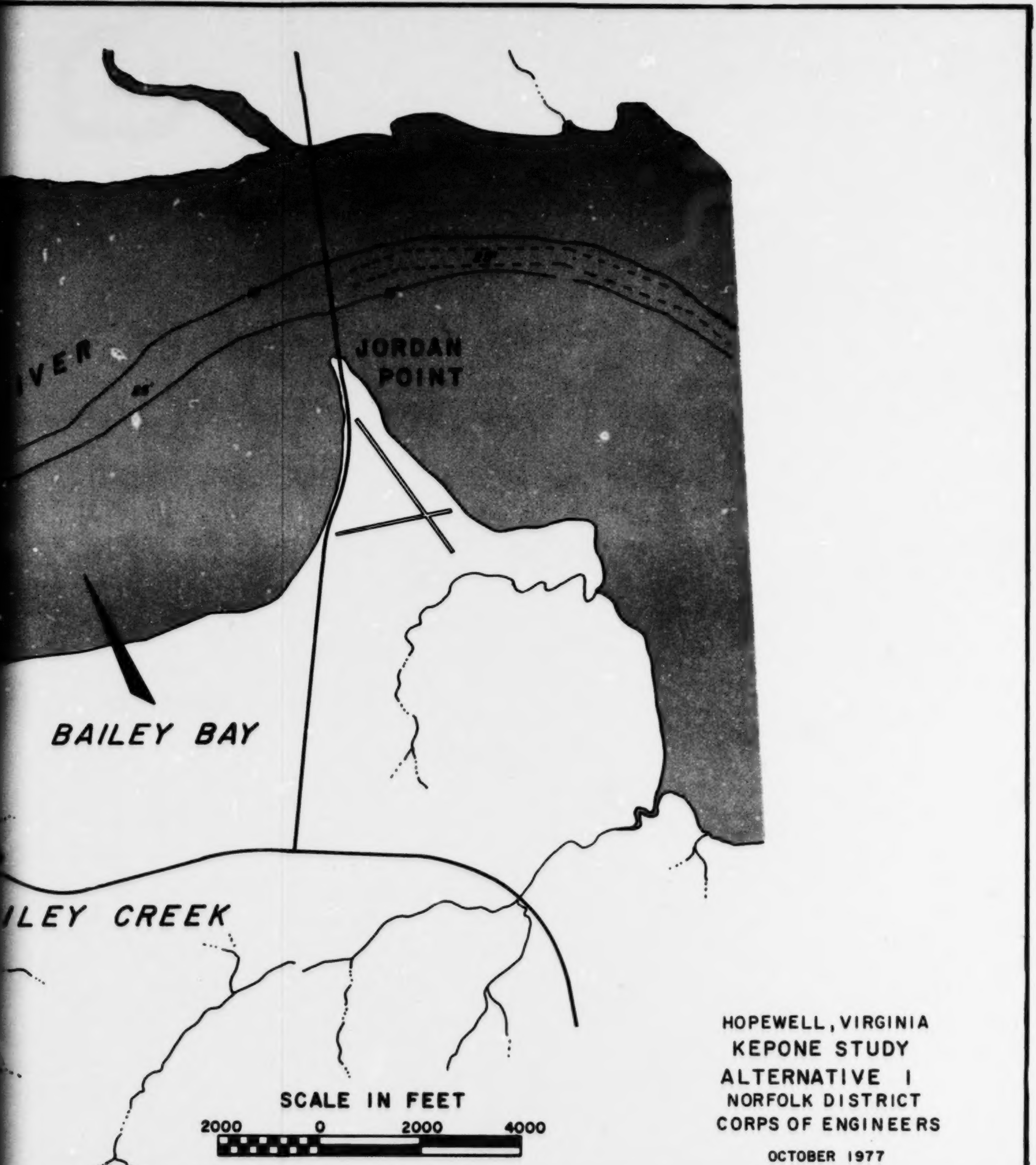

GRAVELLY RUN WATERSHED
BAILEY CREEK WATERSHED
JAMES RIVER
TAR BAY
BAILEY
CREEK
FORT LEE MILITARY RESERVATION
MARYLAND
VIRGINIA
DEL
WASHINGTON
PROJECT LOCATION
NORTH CAROLINA
ATLANTIC OCEAN
LOCATION MAP
SCALE IN MILES
SCALE IN FEET
2000 0 2000 4000
N

HOPEWELL, VIRGINIA
KEPONE STUDY
DRAINAGE AREAS
NORFOLK DISTRICT
CORPS OF ENGINEERS
OCTOBER 1977

PLATE II


CITY POINT
JAMES RIVER
LIFE SCIENCE
ALLIED CHEMICAL CO.
HOPEWELL
CONTINENTAL CAN BRIDGE
RT. 10
BAILE
GRAVELLY RUN
RT. 10
BAILEY CR
SEWAGE TREATMENT PLANT
RT. 156

A


IVER
JORDAN
POINT
BAILEY BAY
ILEY CREEK
SCALE IN FEET
2000 0 2000 4000

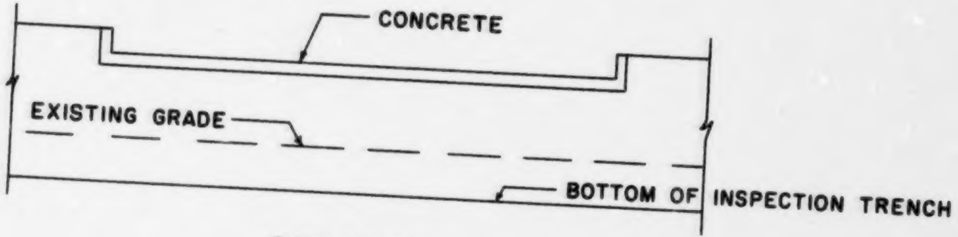
HOPEWELL, VIRGINIA
KEPONE STUDY
ALTERNATIVE I
NORFOLK DISTRICT
CORPS OF ENGINEERS

OCTOBER 1977

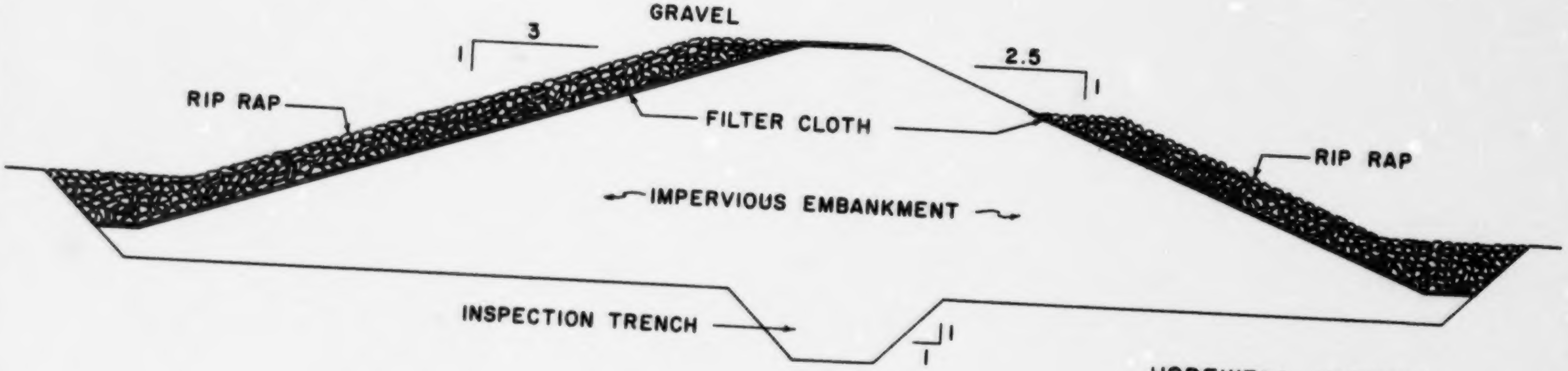
B

135

PLATE 12


CONCRETE
EXISTING GRADE
BOTTOM OF INSPECTION TRENCH

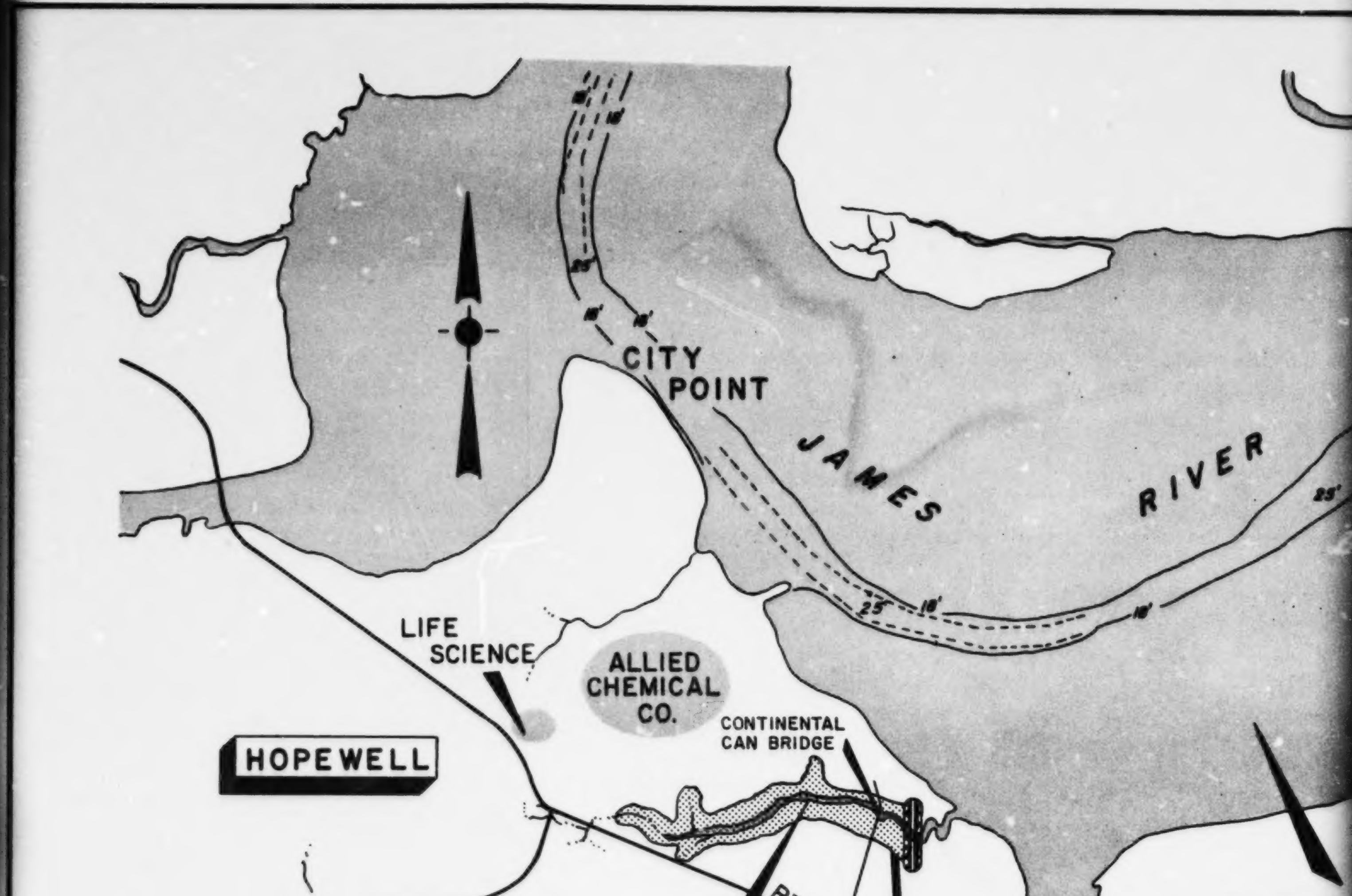
SPILLWAY


GRAVEL
1
3
2.5
1
RIP RAP
FILTER CLOTH
RIP RAP
IMPERVIOUS EMBANKMENT
INSPECTION TRENCH
1
1

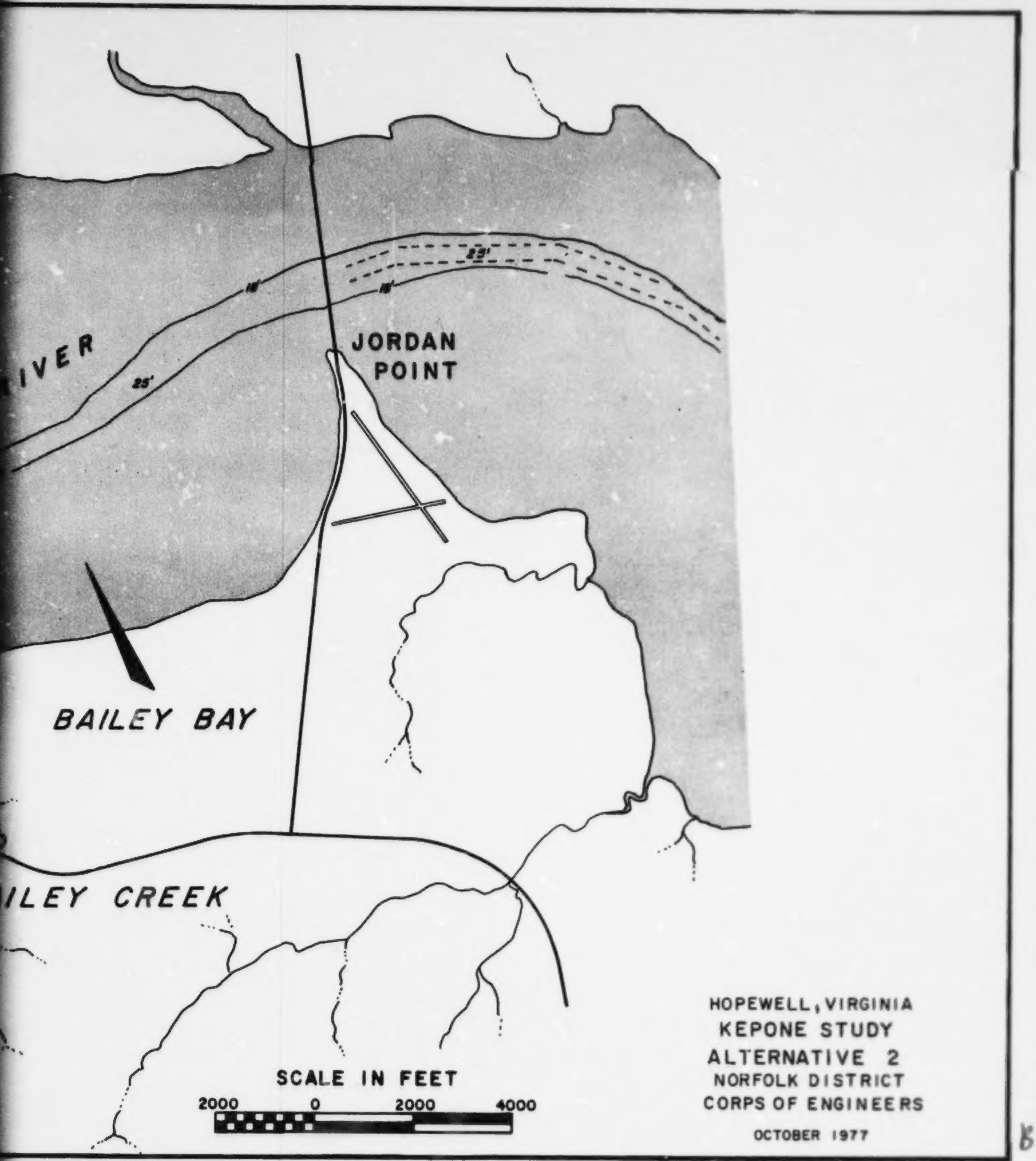
DAM

HOPEWELL, VIRGINIA
KEPONE STUDY
GRAVELLY RUN DAM
TYPICAL SECTIONS
NORFOLK DISTRICT
CORPS OF ENGINEERS

OCTOBER 1977


CITY POINT
JAMES RIVER
25'
18'
LIFE SCIENCE
ALLIED CHEMICAL CO.
HOPEWELL
CONTINENTAL CAN BRIDGE
BAILEY
RT. 10
RT. 10
GRAVELLY RUN
BAILEY CR
SEWAGE TREATMENT PLANT
RT. 156

A


IVER
18'
18'
25'
25'
JORDAN
POINT
BAILEY BAY
ILEY CREEK
SCALE IN FEET
2000
0
2000
4000

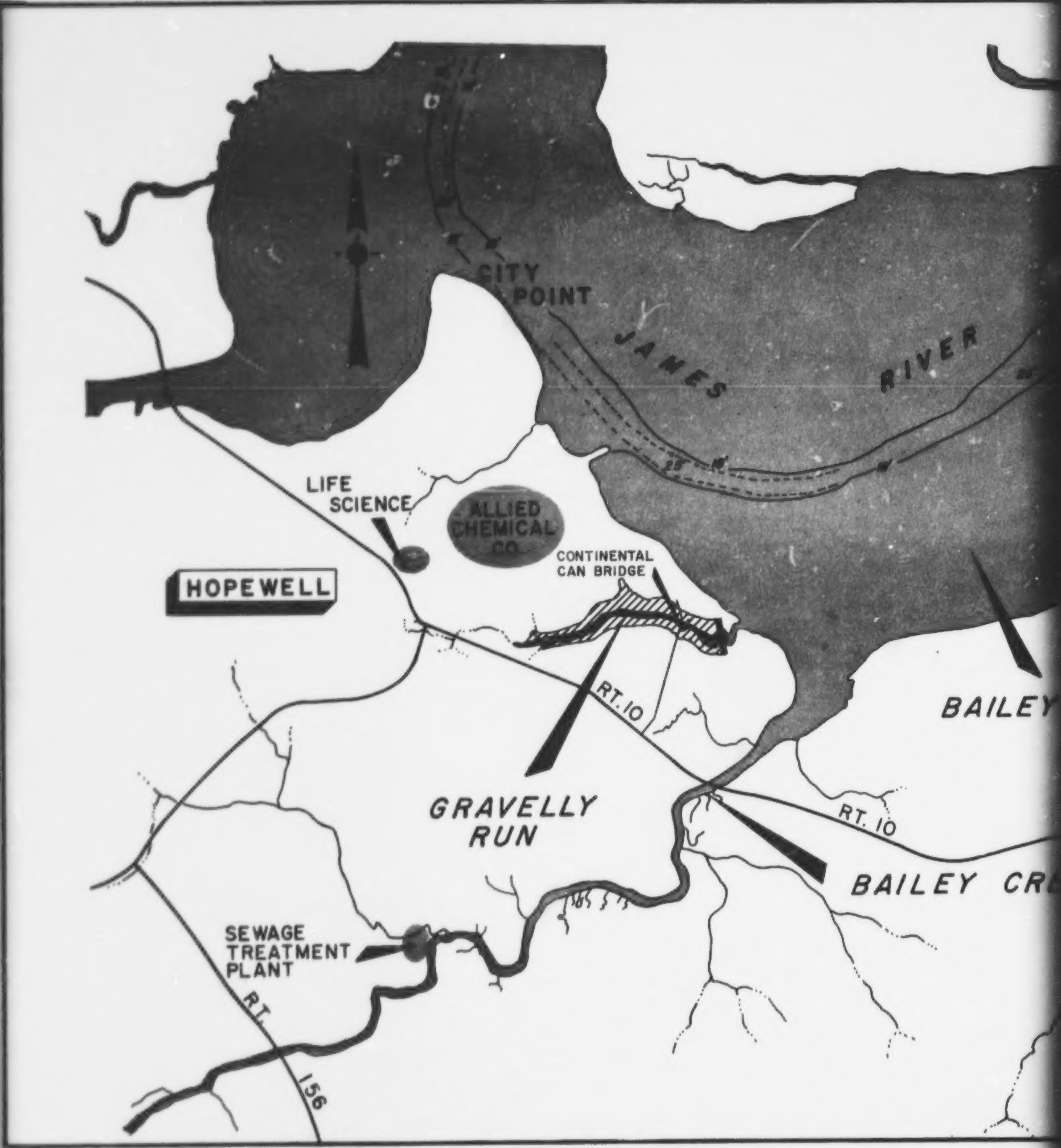
HOPEWELL, VIRGINIA
KEPONE STUDY
ALTERNATIVE 2
NORFOLK DISTRICT
CORPS OF ENGINEERS

OCTOBER 1977

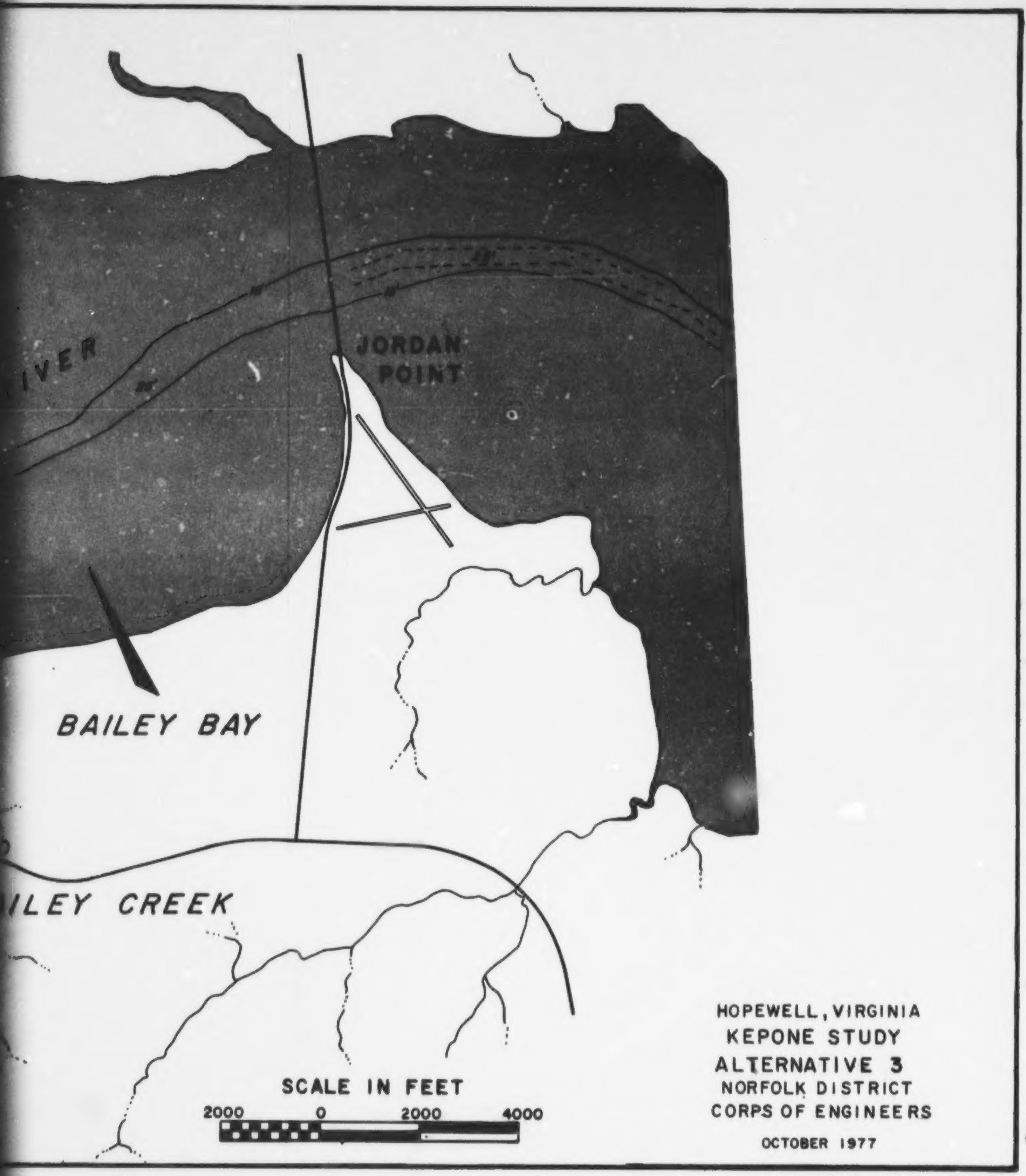
B

137<

PLATE 14


CITY POINT
JAMES RIVER
LIFE SCIENCE
ALLIED CHEMICAL CO.
CONTINENTAL CAN BRIDGE
HOPEWELL
RT. 10
RT. 10
GRAVELLY RUN
BAILEY
BAILEY CR
SEWAGE TREATMENT PLANT
RT. 156
25
16

A


IVER
JORDAN POINT
BAILEY BAY
ILEY CREEK
SCALE IN FEET
2000
0
2000
4000

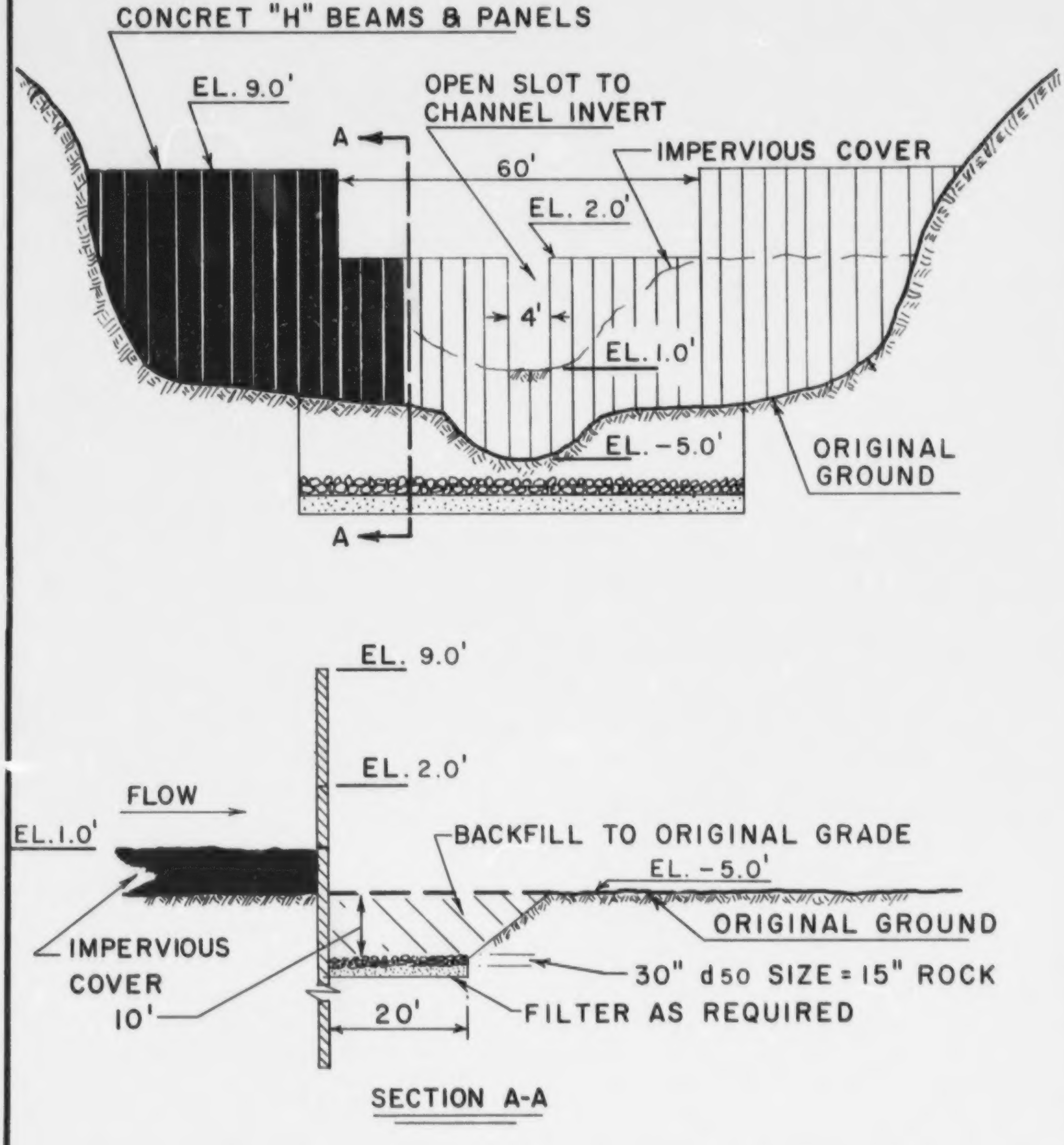
HOPEWELL, VIRGINIA
KEPONE STUDY
ALTERNATIVE 3
NORFOLK DISTRICT
CORPS OF ENGINEERS

OCTOBER 1977

B

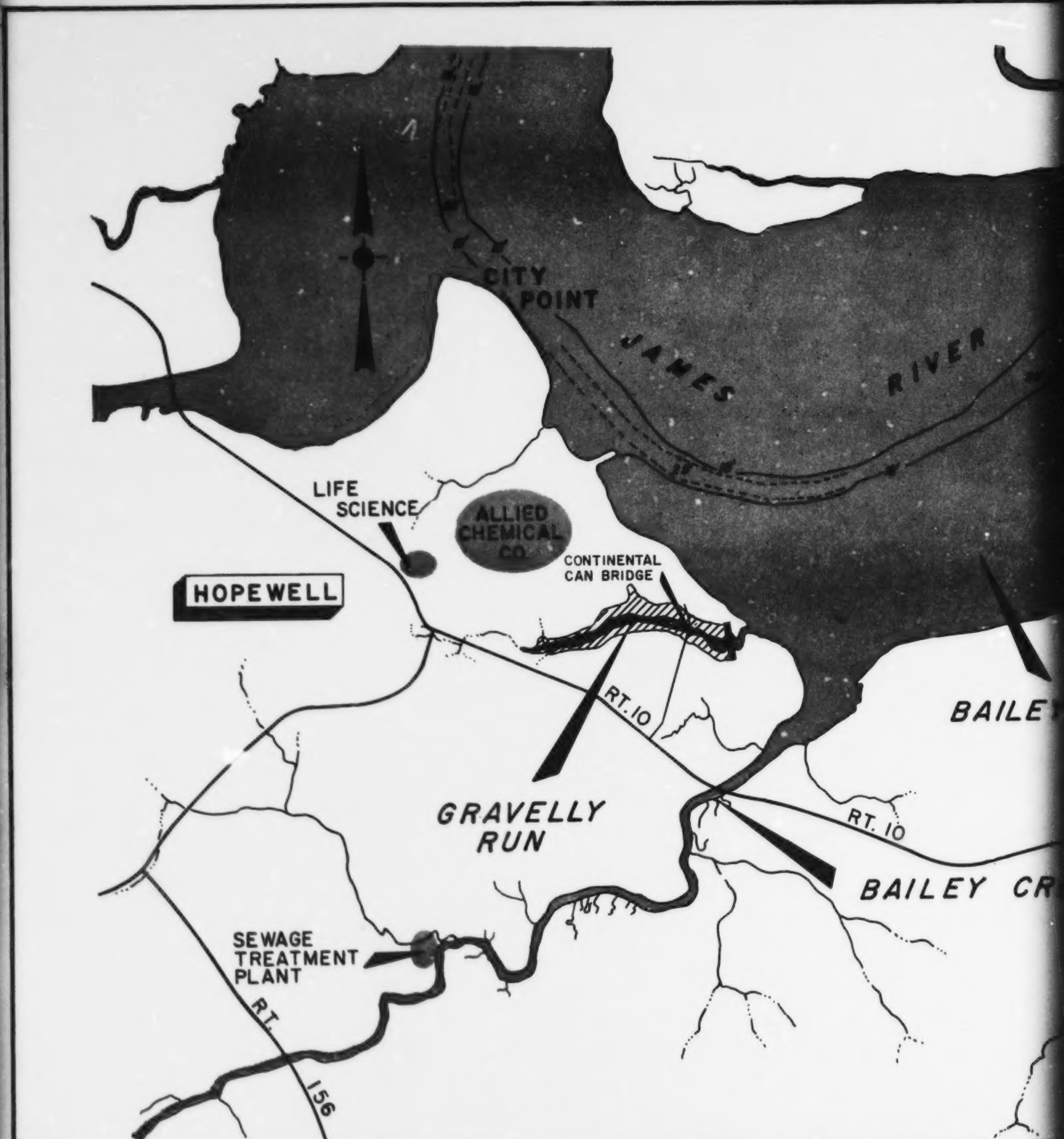
138<

PLATE 15

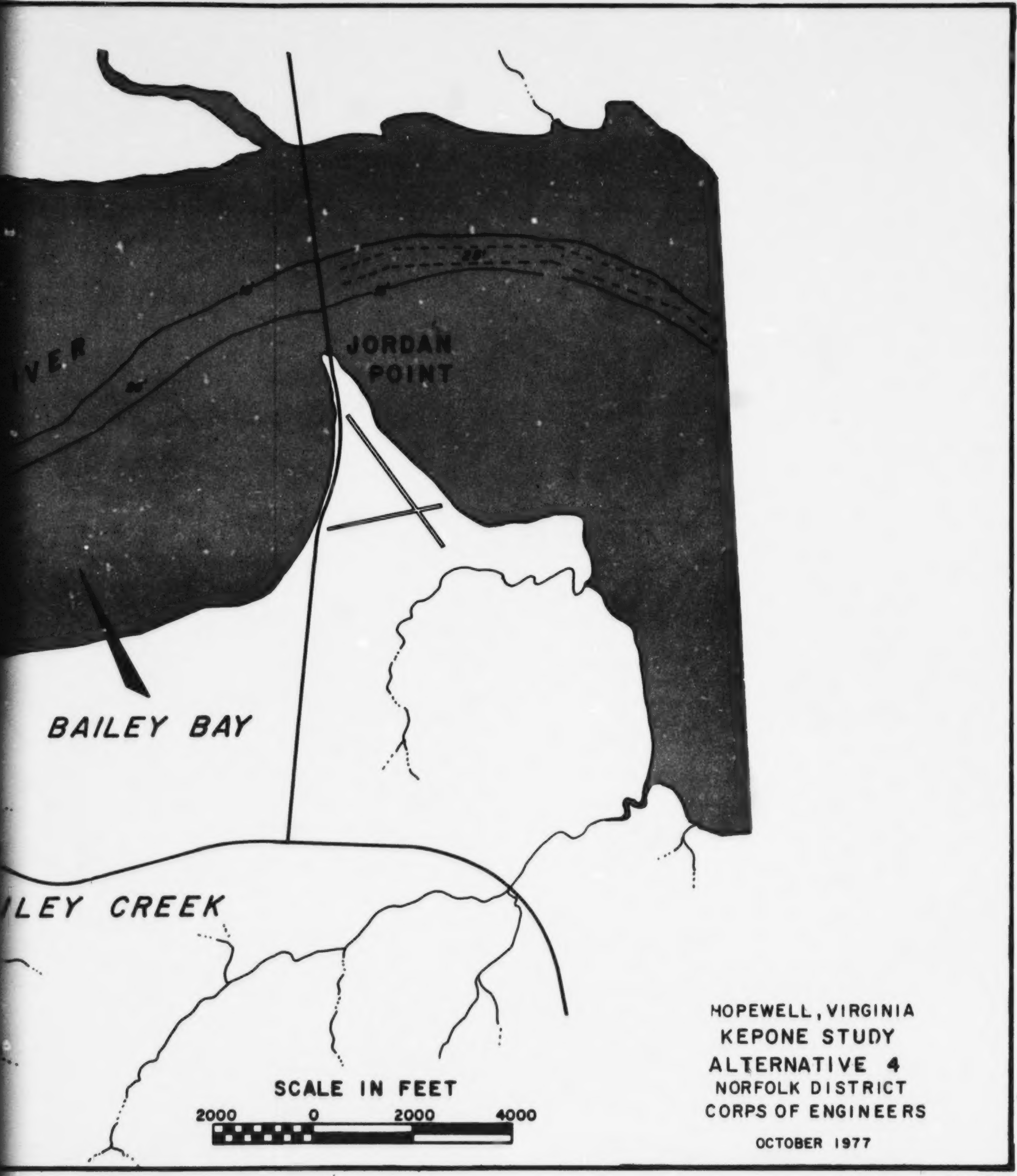

CONCRET "H" BEAMS & PANELS
EL. 9.0'
OPEN SLOT TO CHANNEL INVERT
A
IMPERVIOUS COVER
60'
EL. 2.0'
4'
EL. 1.0'
EL. -5.0'
ORIGINAL GROUND
A
EL. 9.0'
EL. 2.0'
FLOW
EL. 1.0'
BACKFILL TO ORIGINAL GRADE
EL. -5.0'
ORIGINAL GROUND
IMPERVIOUS COVER
30" d50 SIZE = 15" ROCK
10'
20'
FILTER AS REQUIRED
SECTION A-A

NOTE:
NOT TO SCALE

HOPEWELL, VIRGINIA
KEPONE STUDY
GRAVELLY RUN
CONTROL STRUCTURE
NORFOLK DISTRICT
CORPS OF ENGINEERS
OCTOBER 1977


CITY POINT
JAMES RIVER
LIFE SCIENCE
ALLIED CHEMICAL CO.
CONTINENTAL CAN BRIDGE
HOPEWELL
BAILE
RT. 10
RT. 10
GRAVELLY RUN
BAILEY CR
SEWAGE TREATMENT PLANT
RT. 156

A

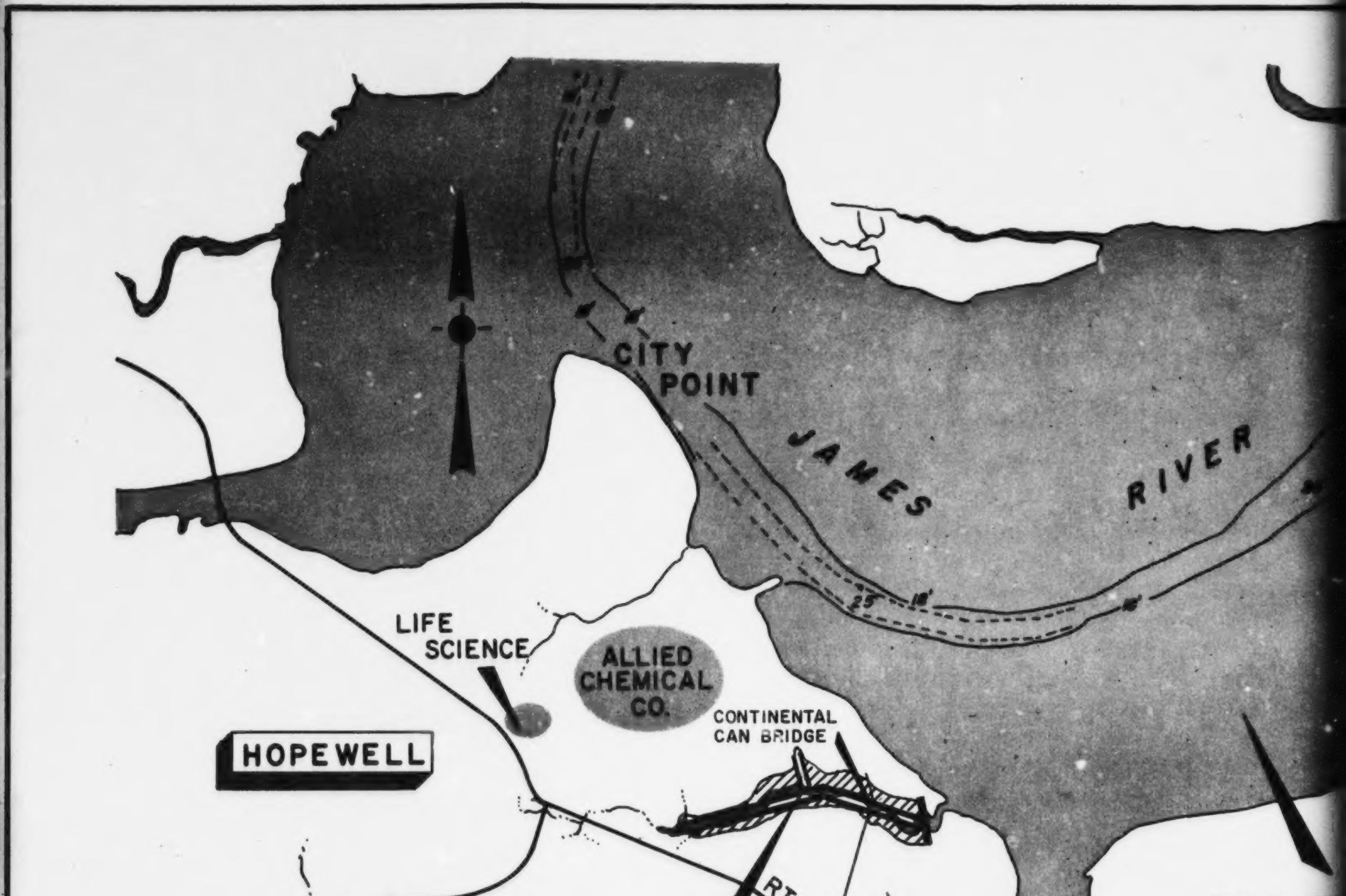

IVER
JORDAN POINT
BAILEY BAY
ILEY CREEK
SCALE IN FEET
2000
0
2000
4000

HOPEWELL, VIRGINIA
KEPONE STUDY
ALTERNATIVE 4
NORFOLK DISTRICT
CORPS OF ENGINEERS

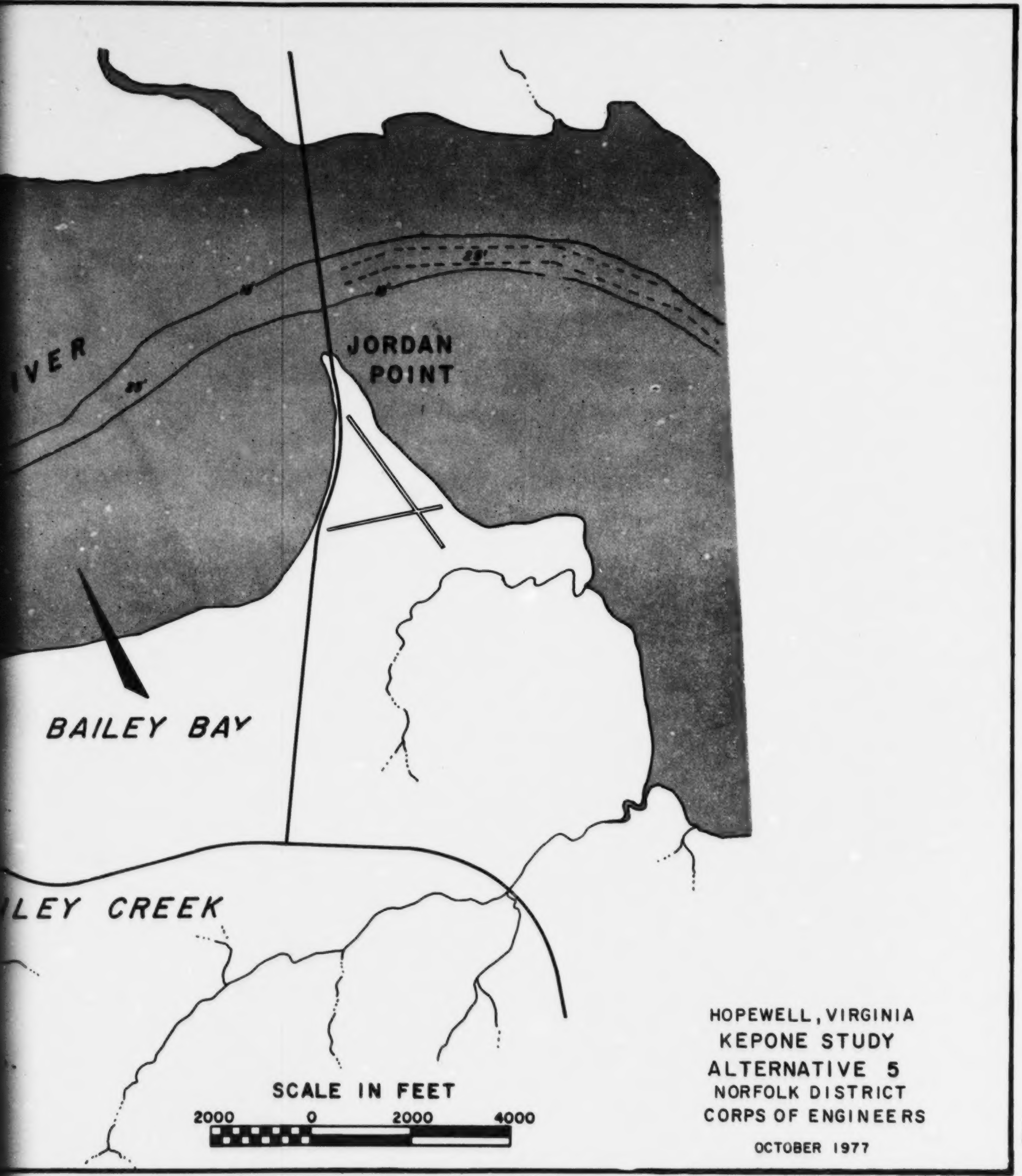
OCTOBER 1977

B

PLATE 17


CITY POINT
JAMES
RIVER
25
18'
18'
LIFE SCIENCE
ALLIED CHEMICAL CO.
HOPEWELL
CONTINENTAL CAN BRIDGE
RT. 10
BAILE
GRAVELLY RUN
RT. 10
BAILEY CR
SEWAGE TREATMENT PLANT
RT. 156

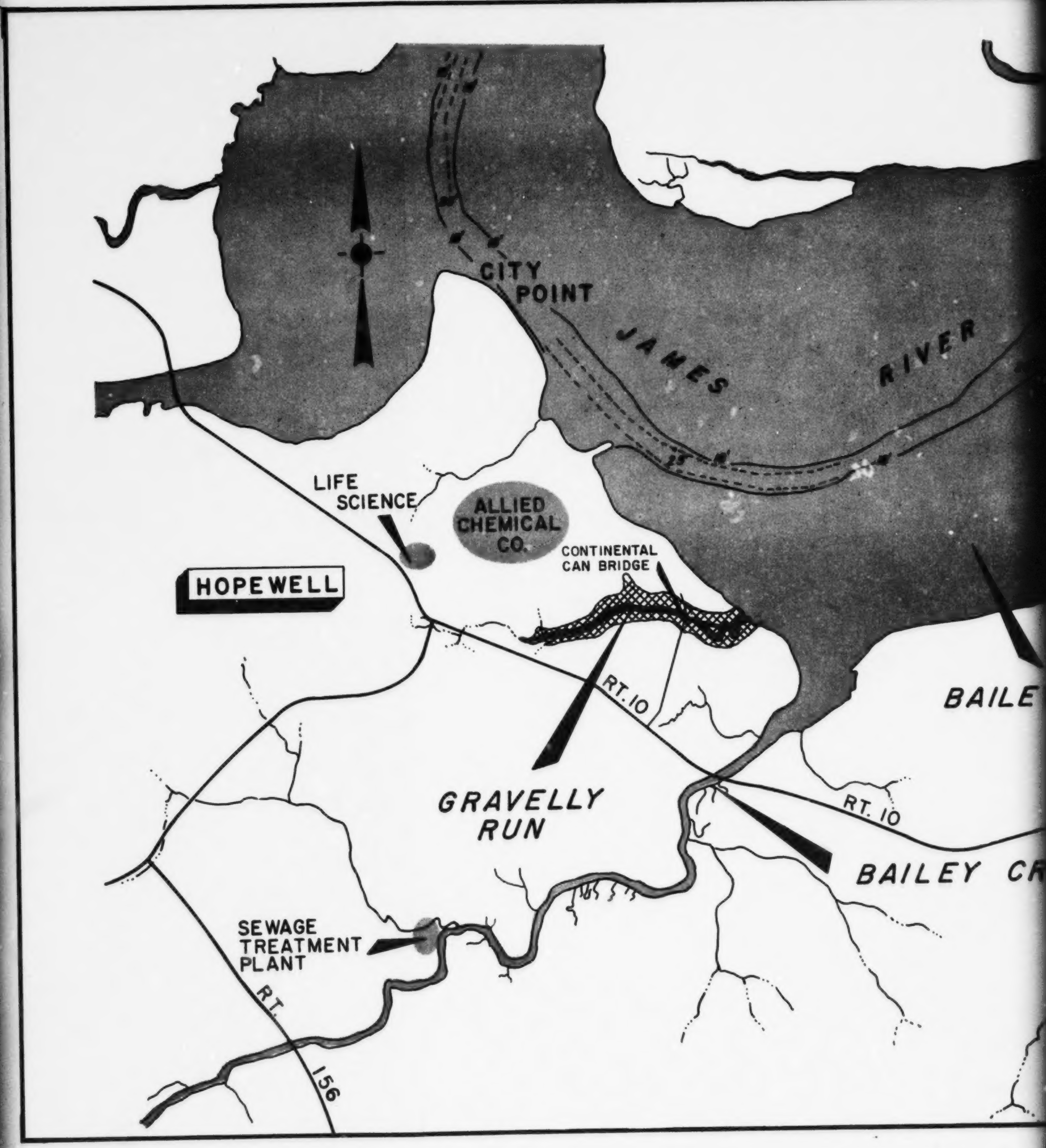
A


IVER
JORDAN POINT
BAILEY BAY
ILEY CREEK
SCALE IN FEET
2000 0 2000 4000

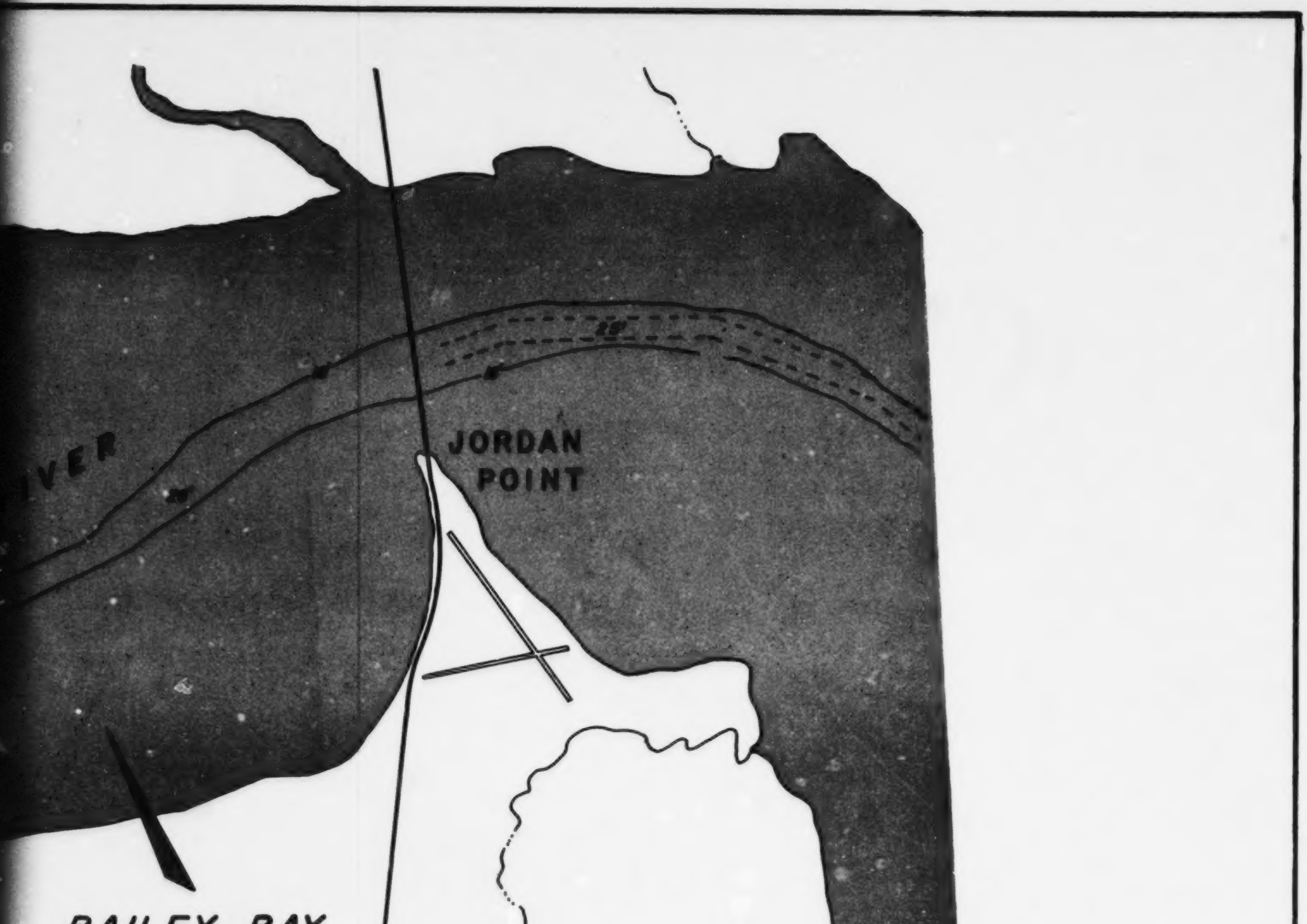
HOPEWELL, VIRGINIA
KEPONE STUDY
ALTERNATIVE 5
NORFOLK DISTRICT
CORPS OF ENGINEERS
OCTOBER 1977

B

PLATE 18


CITY POINT
JAMES RIVER
LIFE SCIENCE
ALLIED CHEMICAL CO.
CONTINENTAL CAN BRIDGE
HOPEWELL
BAILE
RT. 10
GRAVELLY RUN
RT. 10
BAILEY CR
SEWAGE TREATMENT PLANT
RT. 156

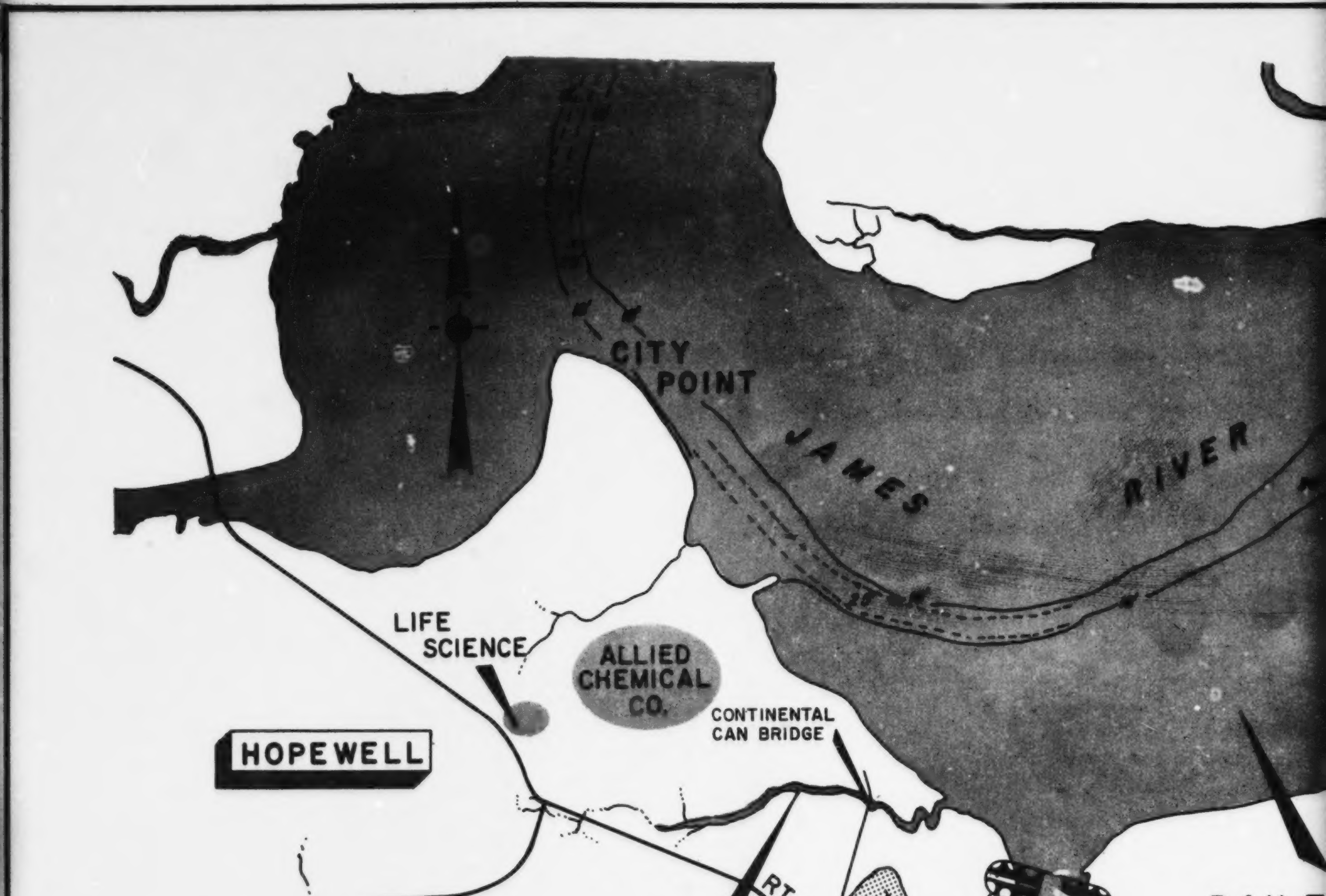
A


IVER
28'
28'
JORDAN
POINT
BAILEY BAY
ILEY CREEK
SCALE IN FEET
2000
0
2000
4000

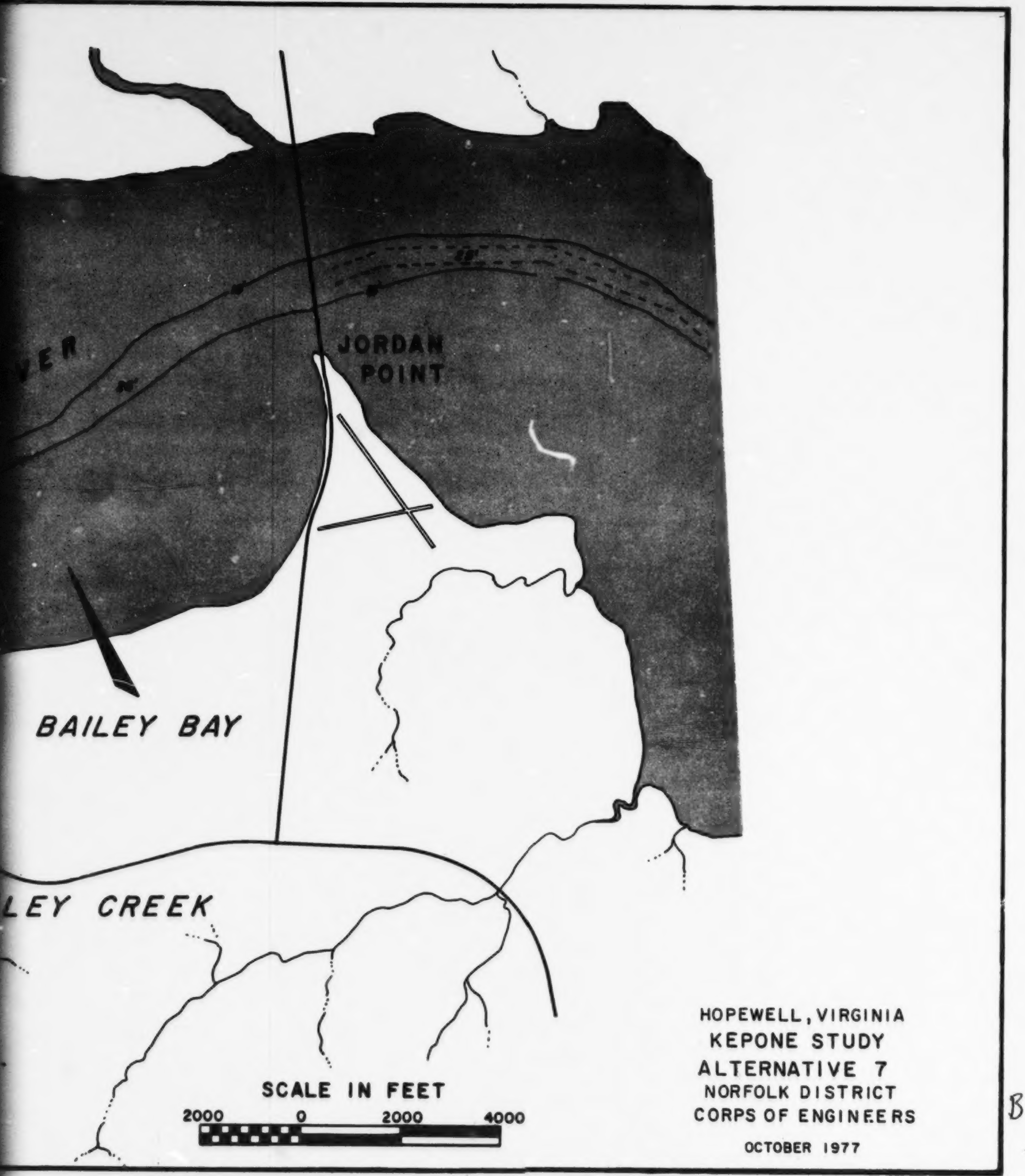
HOPEWELL, VIRGINIA
KEPONE STUDY
ALTERNATIVE 6
NORFOLK DISTRICT
CORPS OF ENGINEERS

OCTOBER 1977

PLATE 19


CITY POINT
JAMES RIVER
LIFE SCIENCE
ALLIED CHEMICAL CO.
CONTINENTAL CAN BRIDGE
HOPEWELL
RT. 10
BAILE
GRAVELLY RUN
RT. 10
BAILEY CR
SEWAGE TREATMENT PLANT
RT. 156

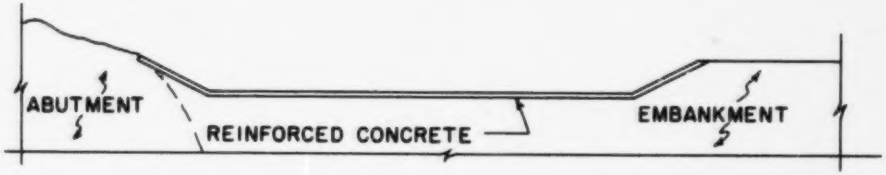
A


VER
JORDAN POINT
BAILEY BAY
LEY CREEK
SCALE IN FEET
2000 0 2000 4000

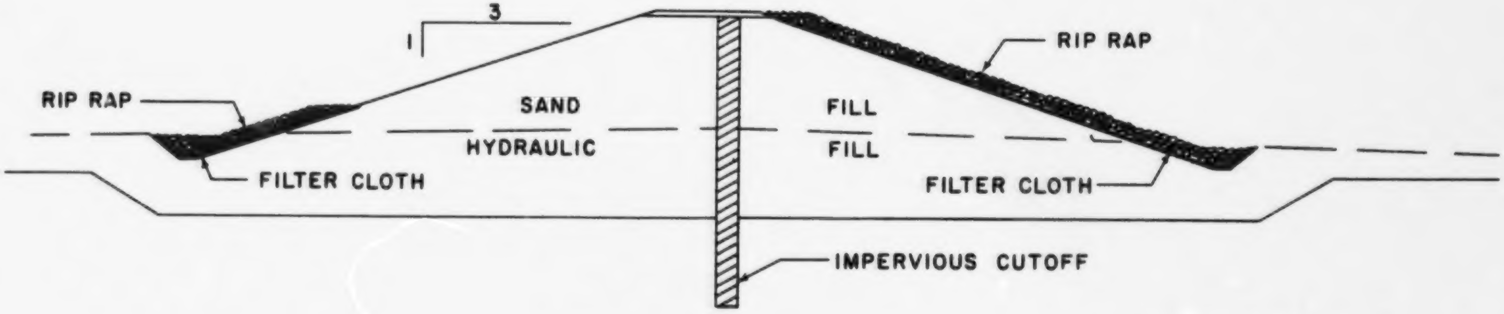
HOPEWELL, VIRGINIA
KEPONE STUDY
ALTERNATIVE 7
NORFOLK DISTRICT
CORPS OF ENGINEERS

OCTOBER 1977

B

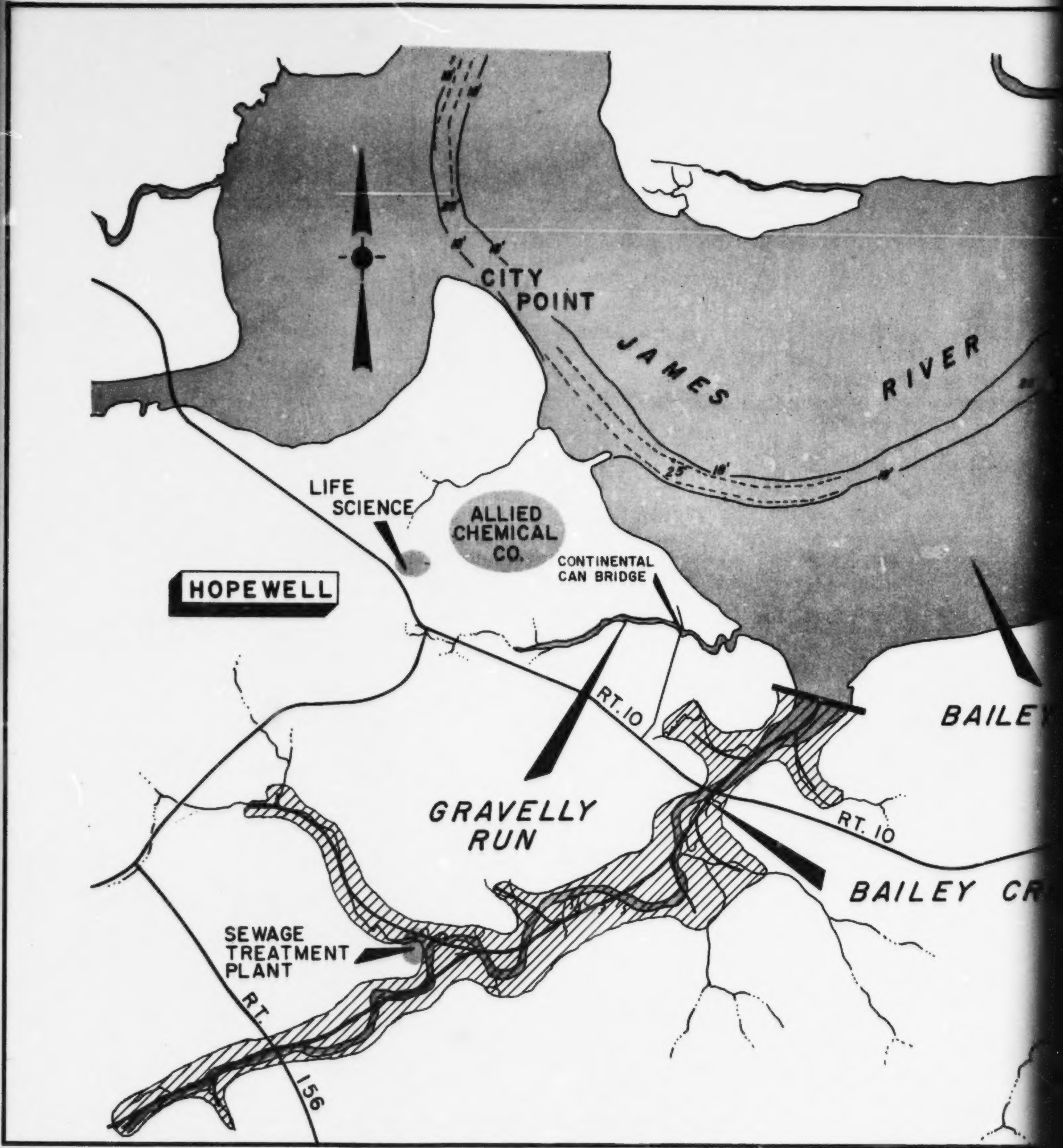

ABUTMENT
REINFORCED CONCRETE
EMBANKMENT

SPILLWAY

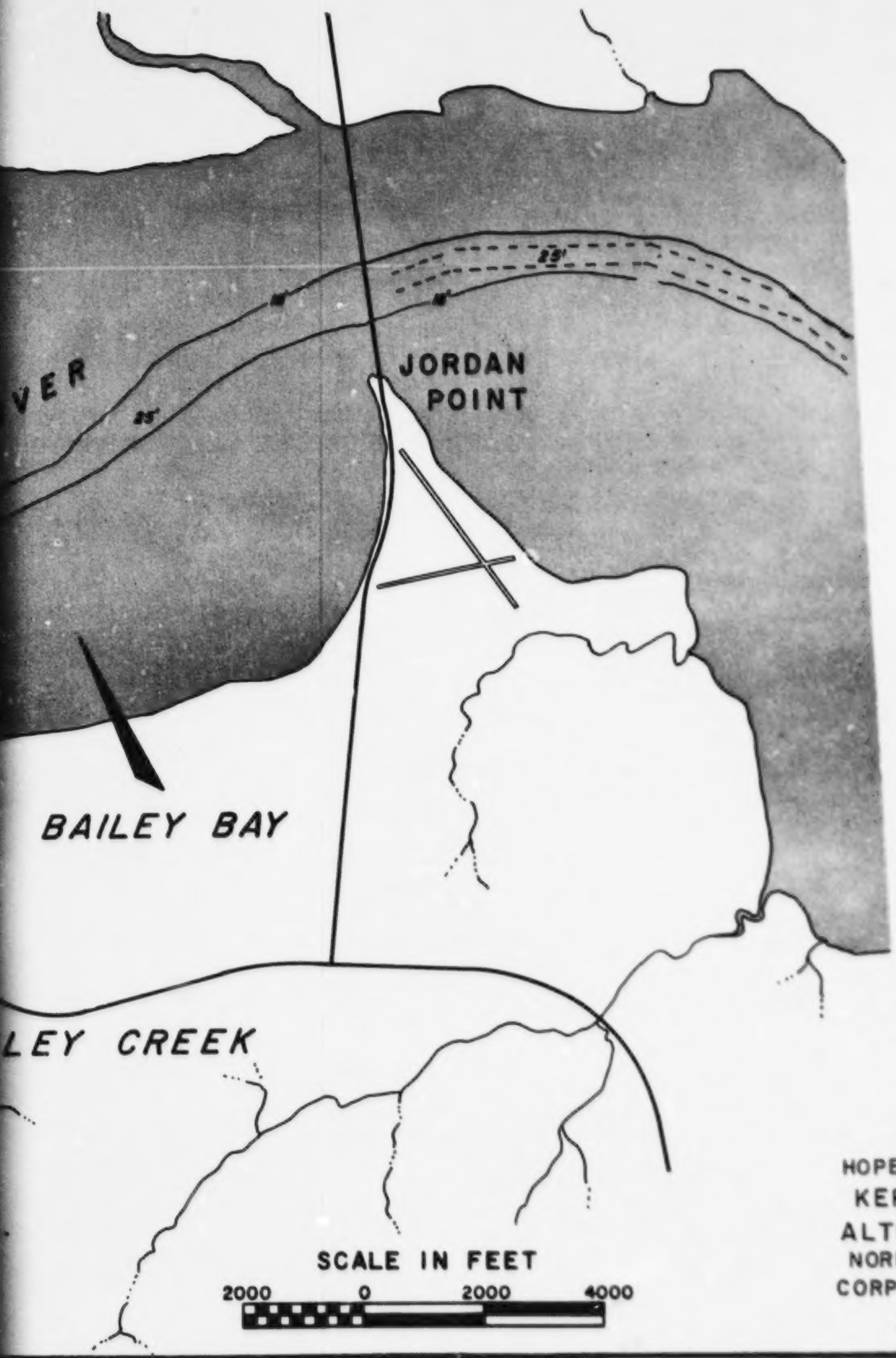

3
1
RIP RAP
SAND
HYDRAULIC
FILTER CLOTH
FILL
FILL
RIP RAP
FILTER CLOTH
IMPERVIOUS CUTOFF

DAM

HOPEWELL, VIRGINIA
KEPONE STUDY
BAILEY CREEK DAM
TYPICAL SECTIONS
NORFOLK DISTRICT
CORPS OF ENGINEERS
OCTOBER 1977


CITY POINT
JAMES RIVER
25'
18'
LIFE SCIENCE
ALLIED CHEMICAL CO.
CONTINENTAL CAN BRIDGE
HOPEWELL
RT. 10
BAILEY
GRAVELLY RUN
RT. 10
BAILEY CR
SEWAGE TREATMENT PLANT
RT. 156

A

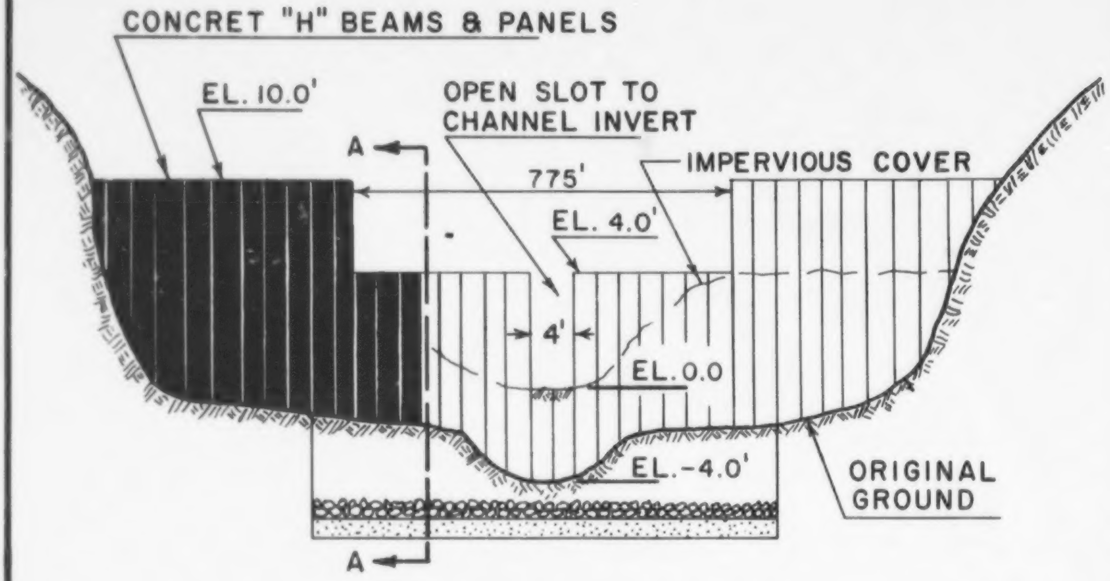

VER
18'
25'
18'
25'
JORDAN
POINT
BAILEY BAY
LEY CREEK
SCALE IN FEET
2000
0
2000
4000

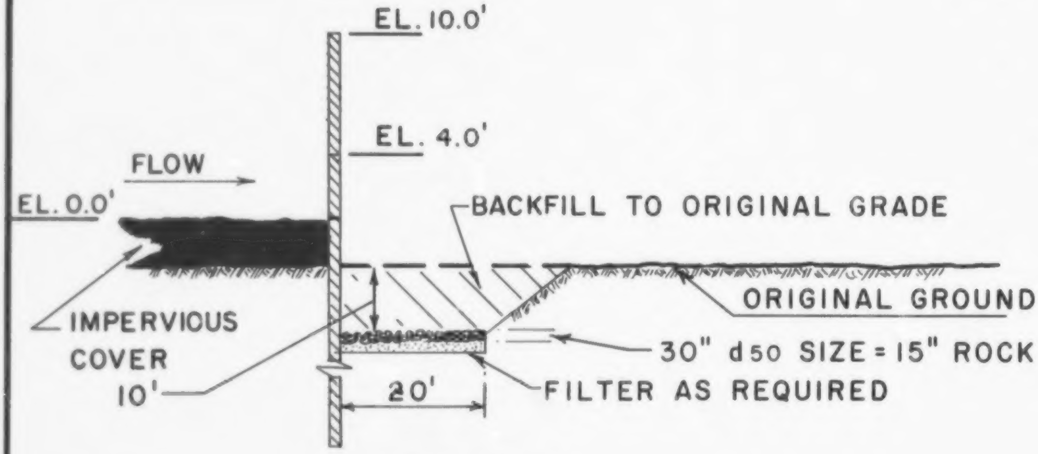
HOPEWELL, VIRGINIA
KEPONE STUDY
ALTERNATIVE 8
NORFOLK DISTRICT
CORPS OF ENGINEERS

OCTOBER 1977

B

PLATE 22

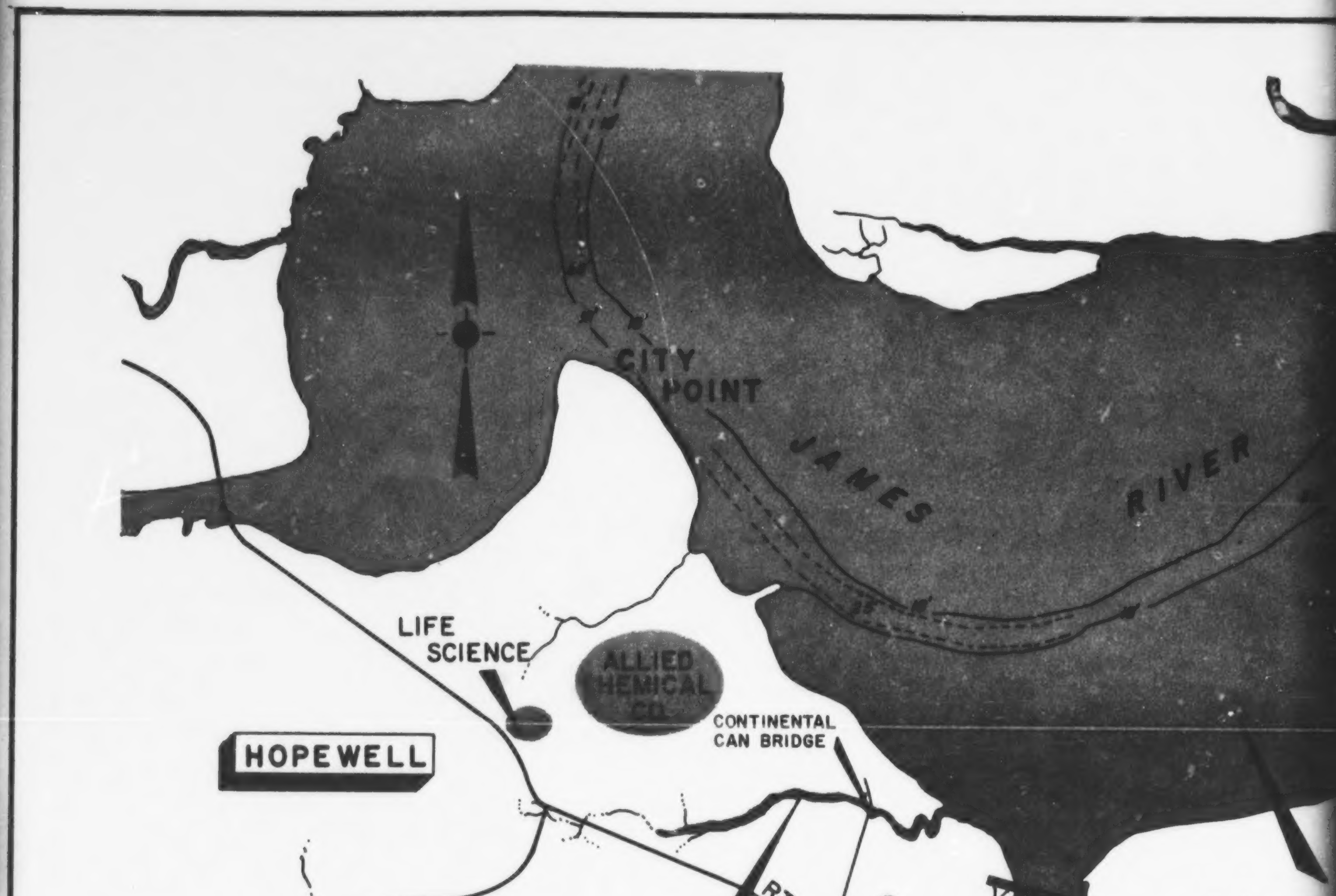

CONCRET "H" BEAMS & PANELS
EL. 10.0'
OPEN SLOT TO CHANNEL INVERT
A
775'
IMPERVIOUS COVER
EL. 4.0'
4'
EL. 0.0
EL. -4.0'
ORIGINAL GROUND
A


EL. 10.0'
EL. 4.0'
FLOW
EL. 0.0'
BACKFILL TO ORIGINAL GRADE
ORIGINAL GROUND
IMPERVIOUS COVER
30" d50 SIZE = 15" ROCK
10'
FILTER AS REQUIRED
20'

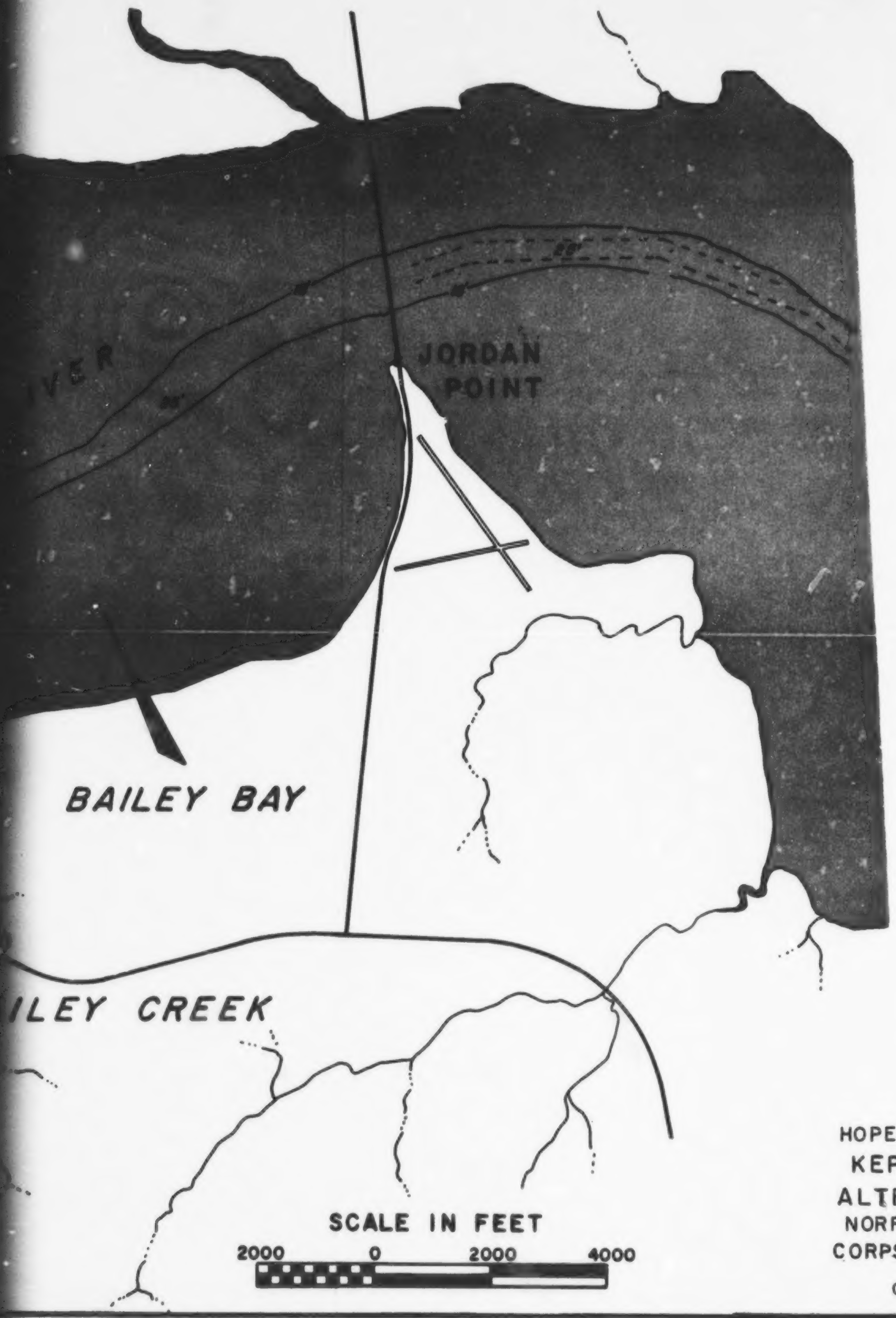
SECTION A-A

NOTE:
NOT TO SCALE

HOPEWELL, VIRGINIA
KEPONE STUDY
BAILEY CREEK
CONTROL STRUCTURE
NORFOLK DISTRICT
CORPS OF ENGINEERS
OCTOBER 1977


CITY POINT
JAMES RIVER
LIFE SCIENCE
ALLIED HEMICAL CO.
HOPEWELL
CONTINENTAL CAN BRIDGE
RT. 10
BAILE
GRAVELLY RUN
RT. 10
BAILEY CR
SEWAGE TREATMENT PLANT
RT. 156

A


IVER
JORDAN POINT
BAILEY BAY
ILEY CREEK
SCALE IN FEET
2000
0
2000
4000

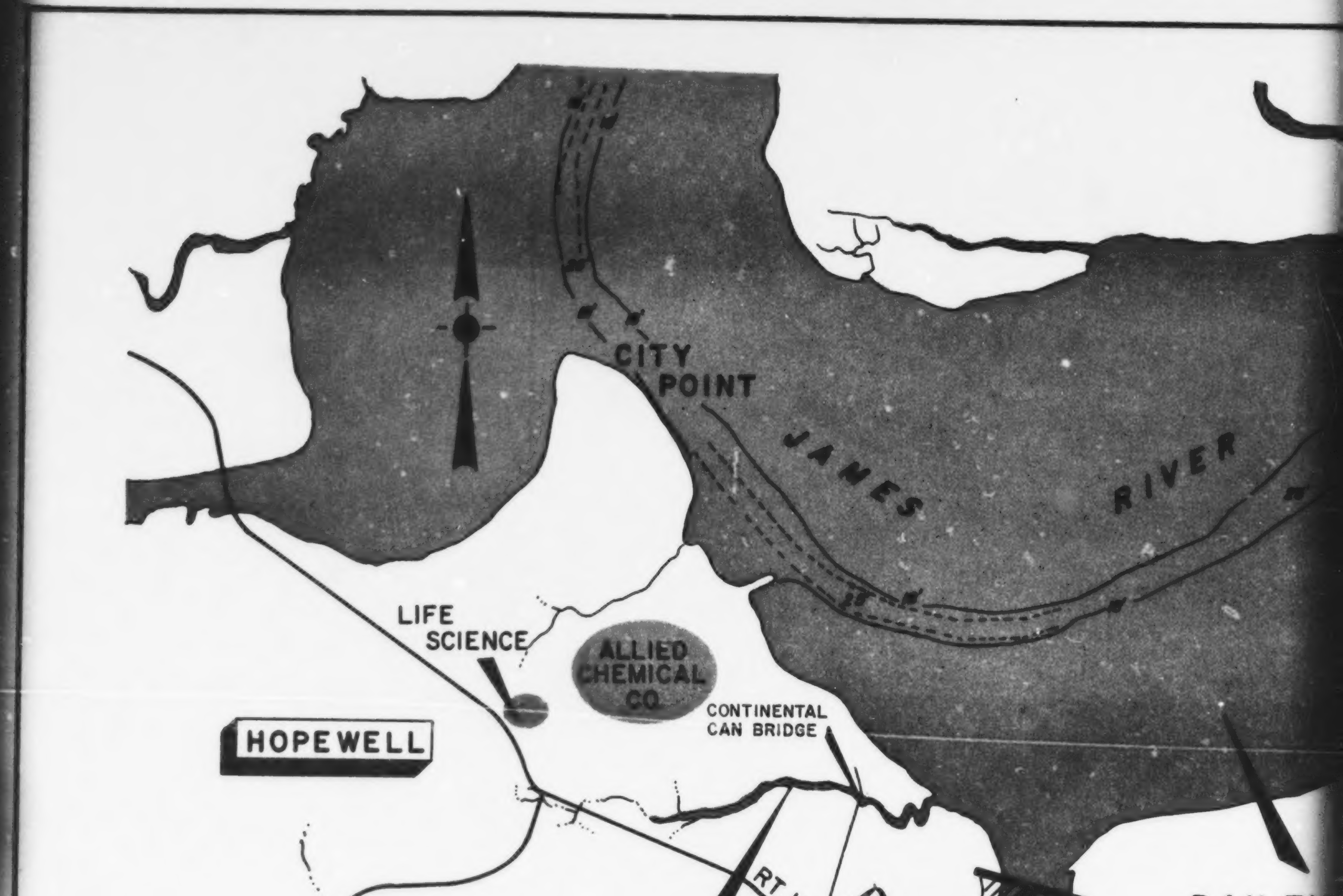
HOPEWELL, VIRGINIA
KEPONE STUDY
ALTERNATIVE 9
NORFOLK DISTRICT
CORPS OF ENGINEERS

OCTOBER 1977

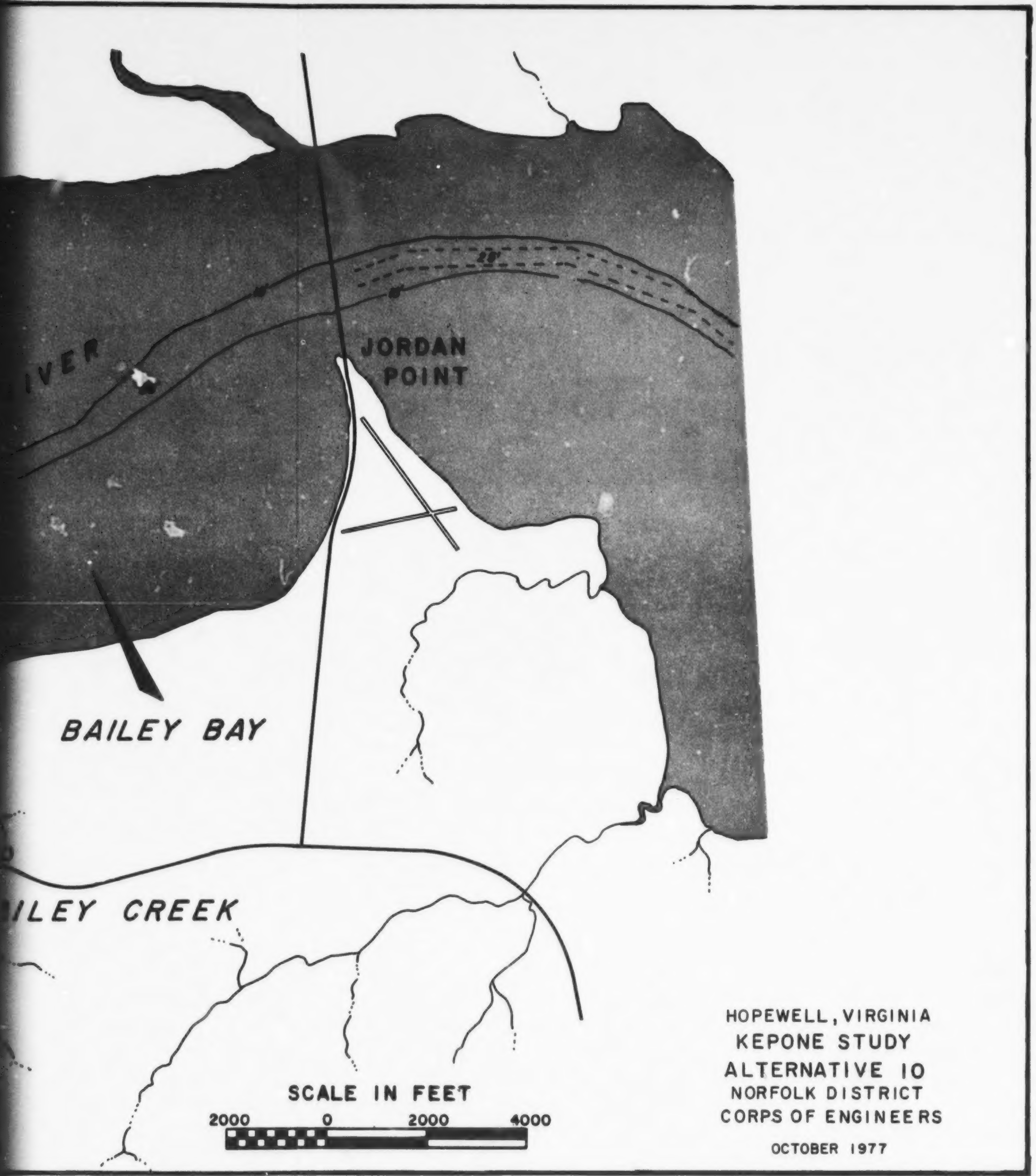
B

147<

PLATE 24


CITY POINT
JAMES RIVER
LIFE SCIENCE
ALLIED CHEMICAL CO.
HOPEWELL
CONTINENTAL CAN BRIDGE
RT. 10
BAILEY
GRAVELLY RUN
RT. 10
BAILEY CR
SEWAGE TREATMENT PLANT
RT. 156

A

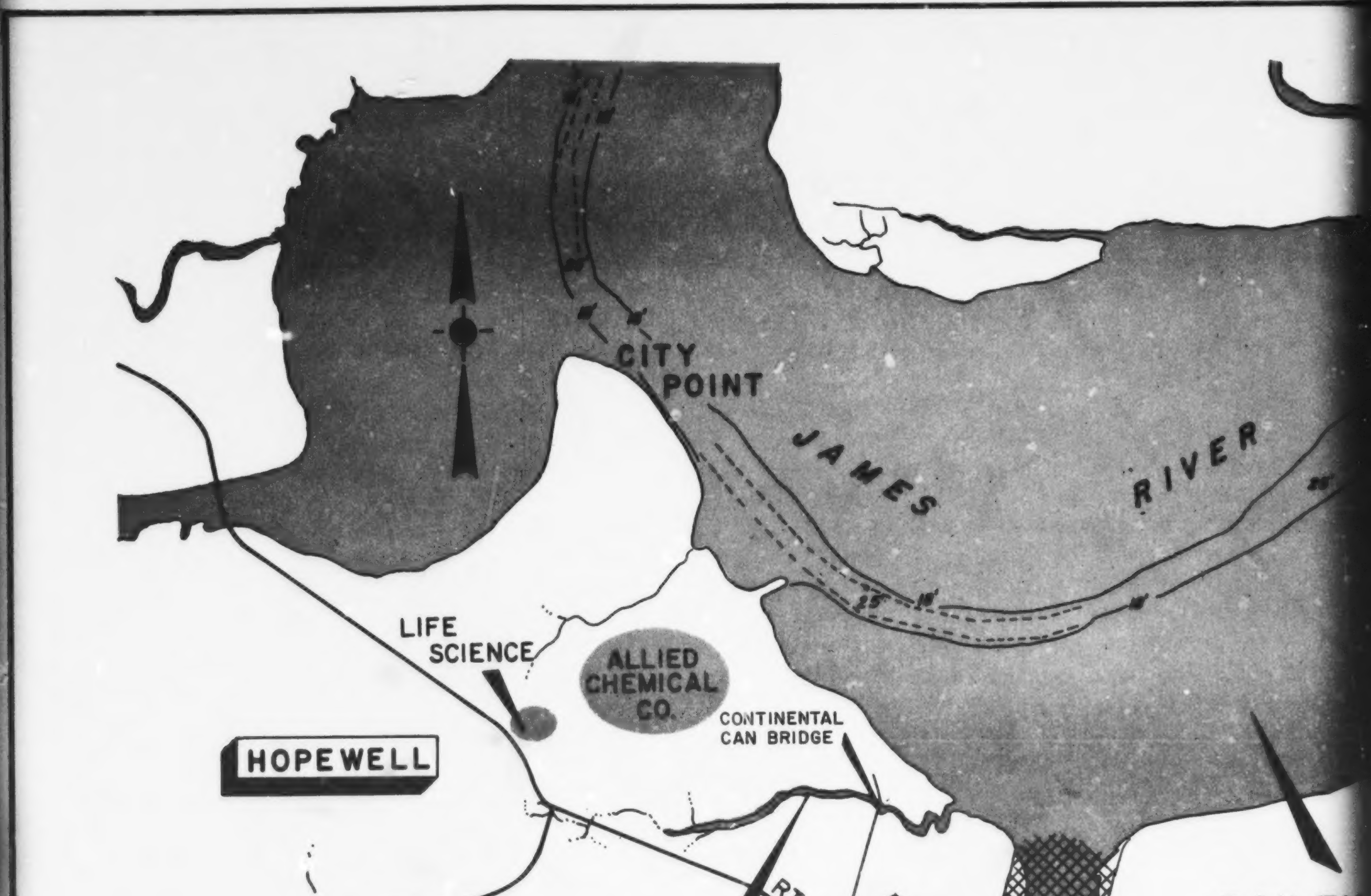

IVER
JORDAN POINT
BAILEY BAY
ILEY CREEK
SCALE IN FEET
2000
0
2000
4000

HOPEWELL, VIRGINIA
KEPONE STUDY
ALTERNATIVE 10
NORFOLK DISTRICT
CORPS OF ENGINEERS

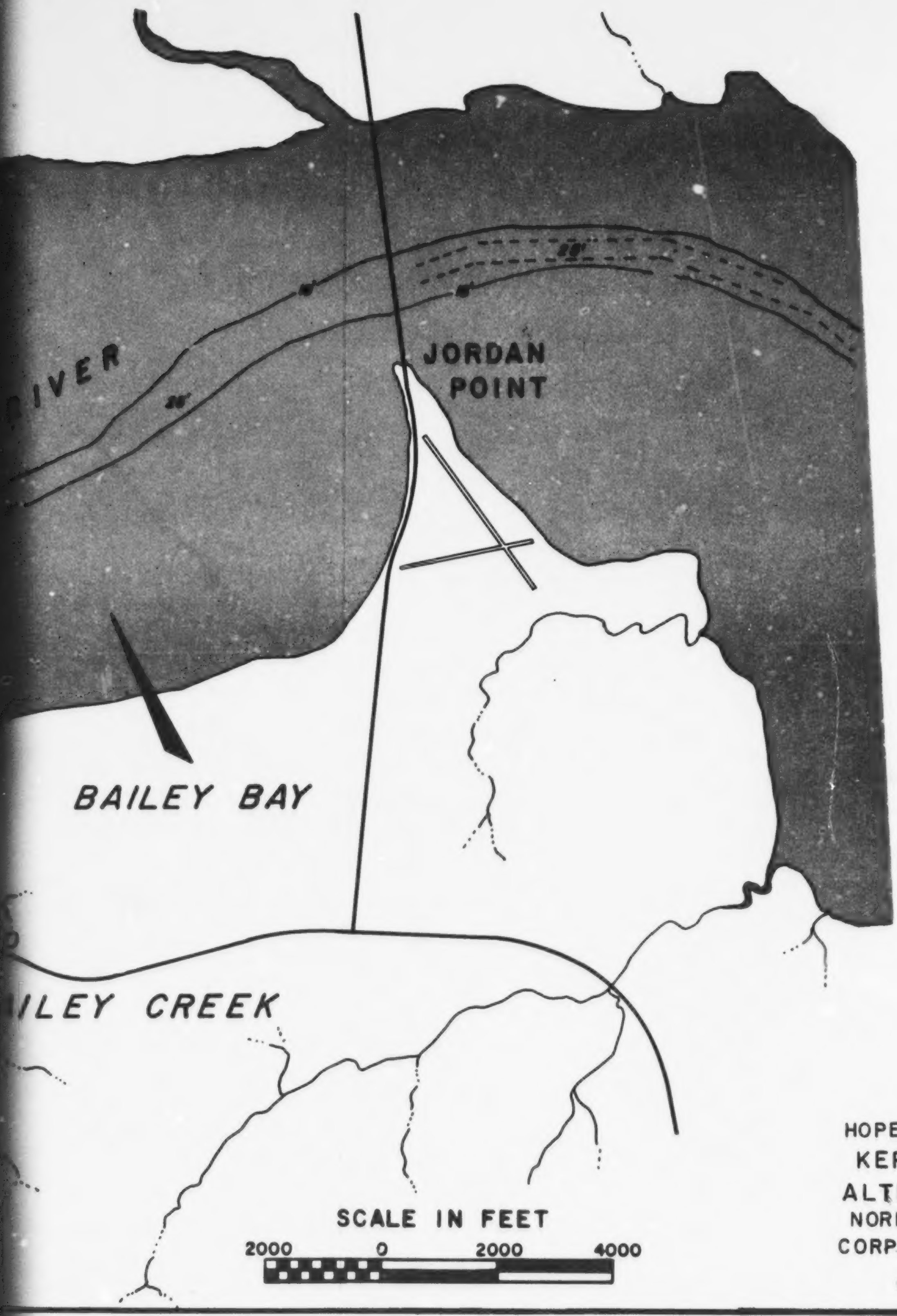
OCTOBER 1977

B

PLATE 25


CITY POINT
JAMES RIVER
LIFE SCIENCE
ALLIED CHEMICAL CO.
CONTINENTAL CAN BRIDGE
HOPEWELL
RT. 10
RT. 10
BAILEY
GRAVELLY RUN
BAILEY CRE
SEWAGE TREATMENT PLANT
RT. 156
25'
15'
25'

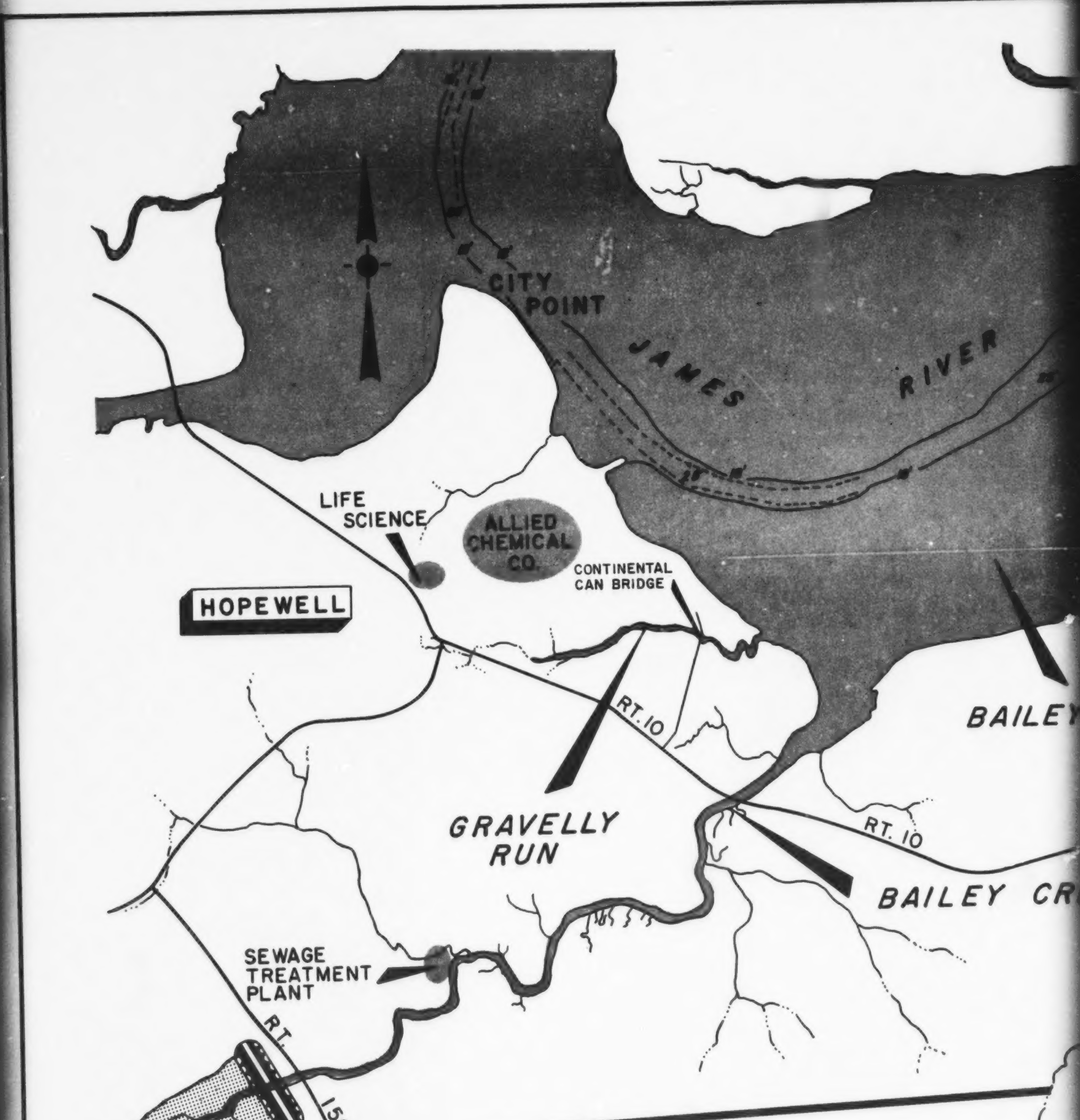
A


RIVER
28'
25'
JORDAN
POINT
BAILEY BAY
ILEY CREEK
SCALE IN FEET
2000
0
2000
4000

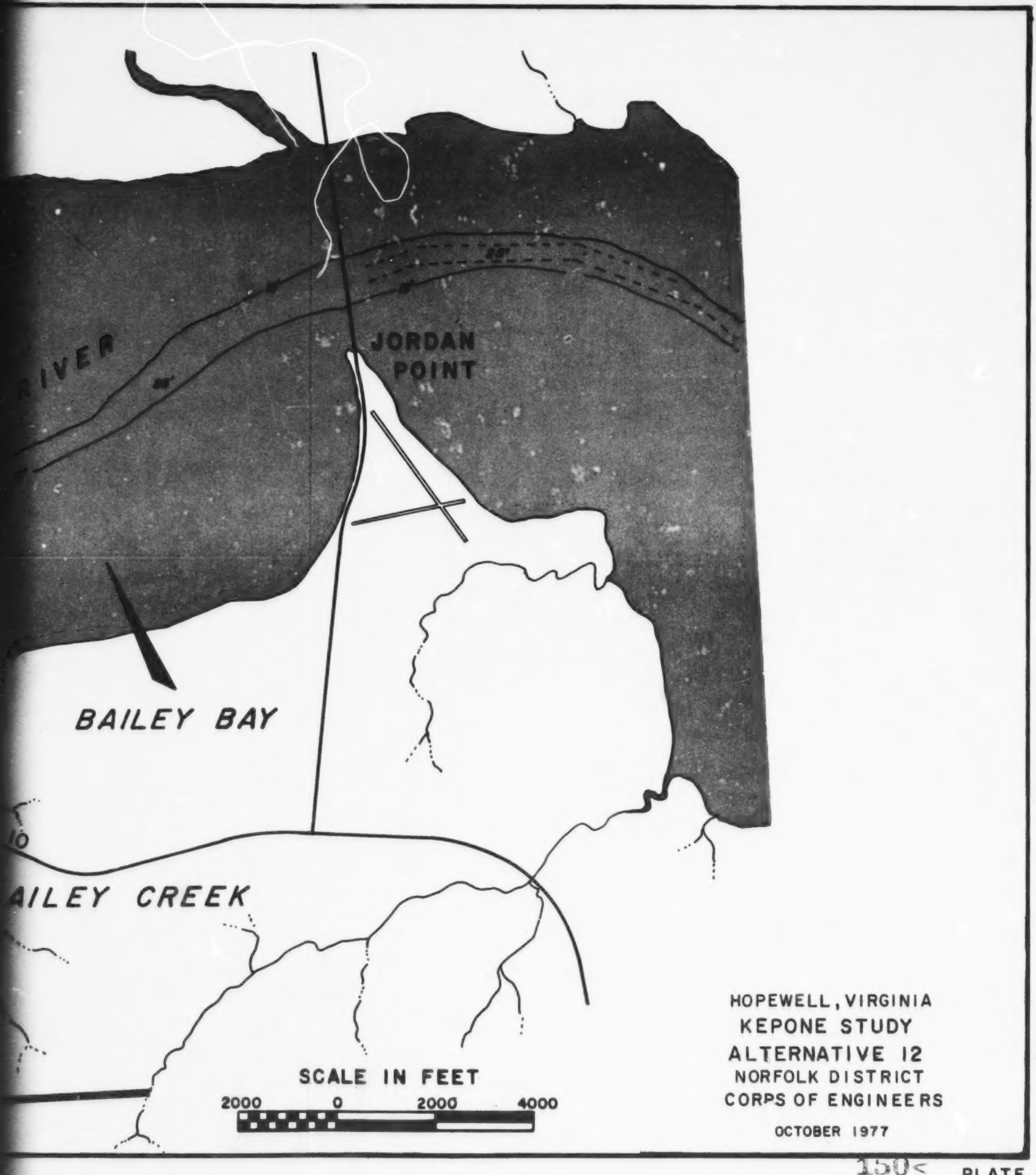
HOPEWELL, VIRGINIA
KEPONE STUDY
ALTERNATIVE II
NORFOLK DISTRICT
CORPS OF ENGINEERS

OCTOBER 1977

B


CITY POINT
JAMES RIVER
LIFE SCIENCE
ALLIED CHEMICAL CO.
CONTINENTAL CAN BRIDGE
HOPEWELL
RT. 10
BAILEY
GRAVELLY RUN
RT. 10
BAILEY CR
SEWAGE TREATMENT PLANT
RT. 156

A


RIVER
28'
JORDAN POINT
BAILEY BAY
10
AILEY CREEK
SCALE IN FEET
2000
0
2000
4000

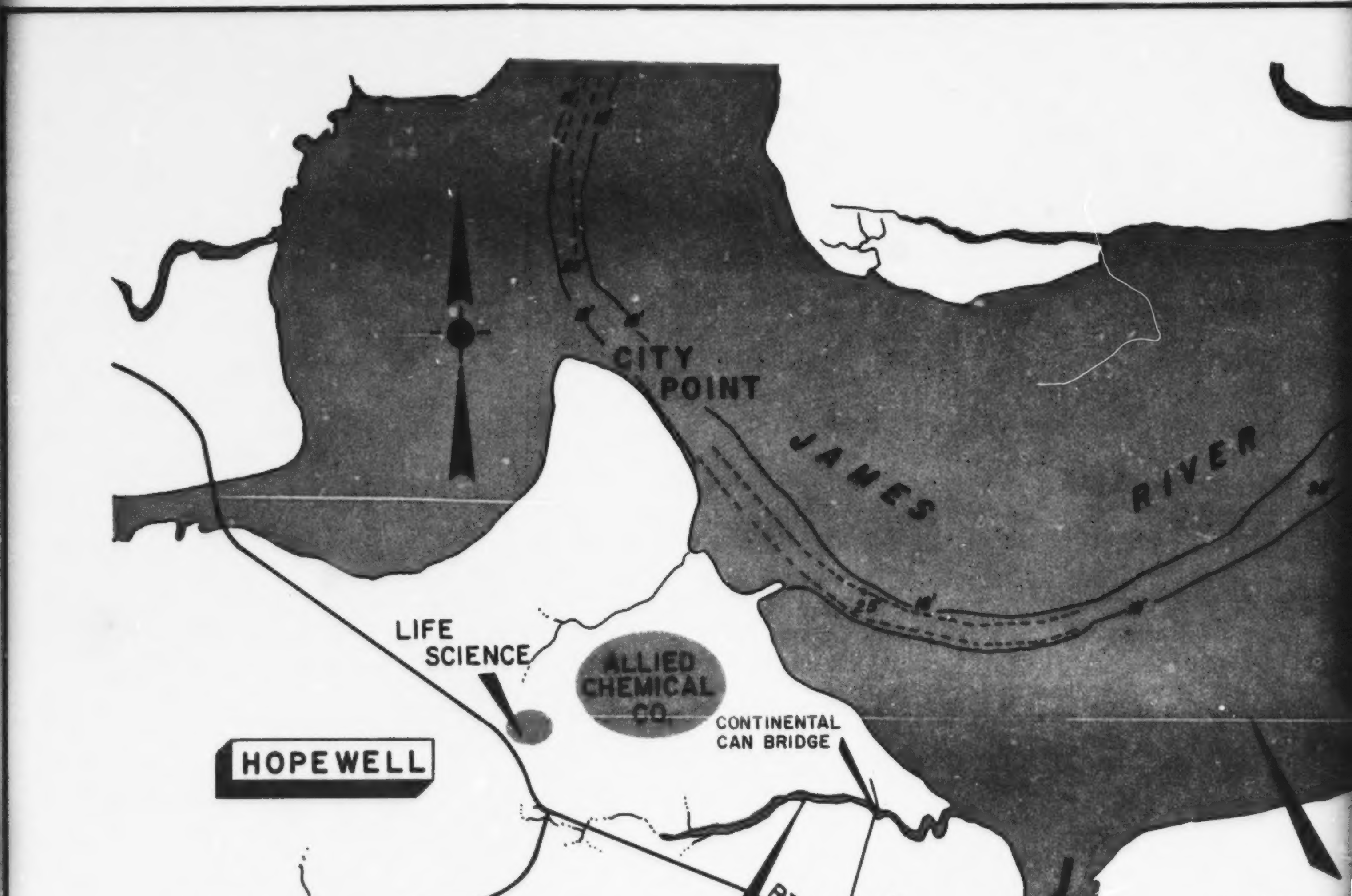
HOPEWELL, VIRGINIA
KEPONE STUDY
ALTERNATIVE 12
NORFOLK DISTRICT
CORPS OF ENGINEERS

OCTOBER 1977

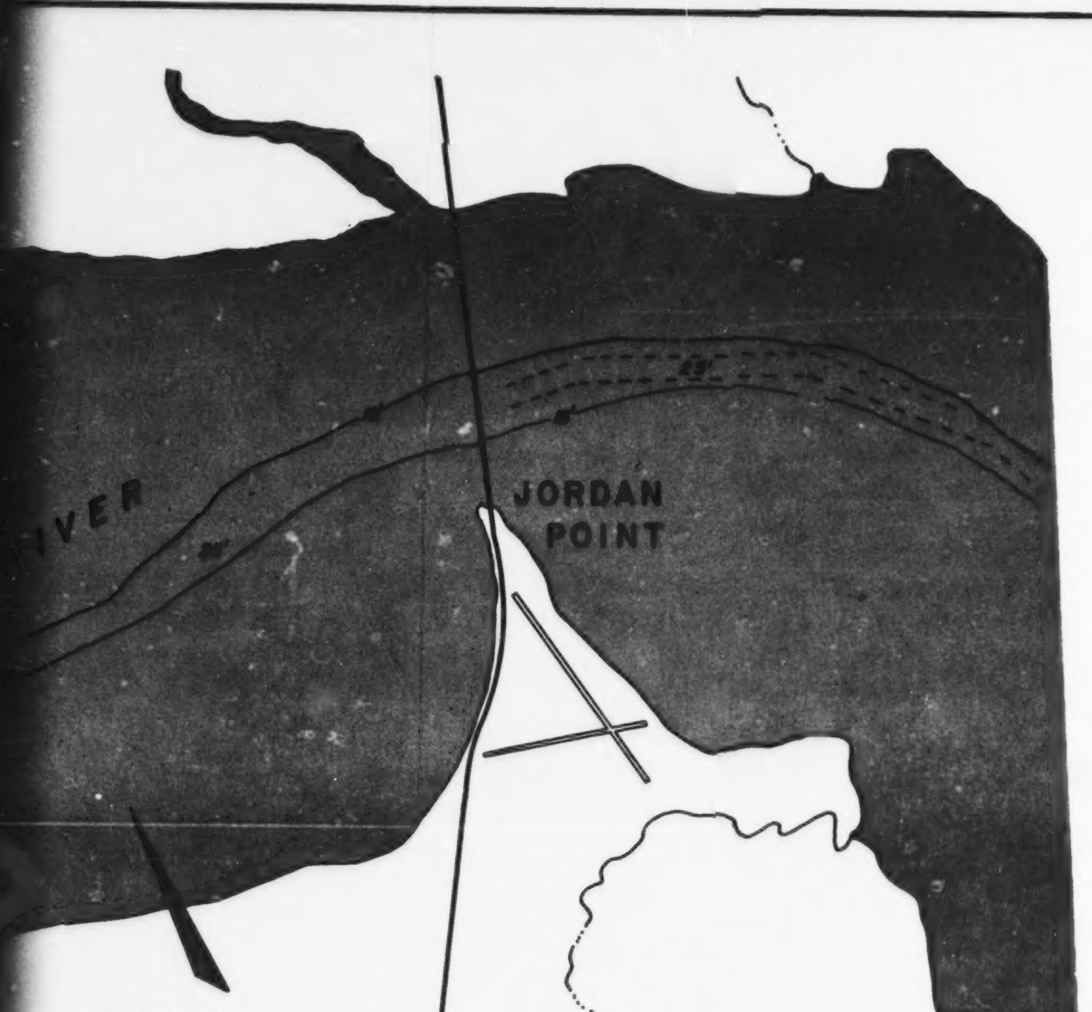
B

150<

PLATE 27


CITY POINT
JAMES RIVER
25
LIFE SCIENCE
ALLIED CHEMICAL CO.
CONTINENTAL CAN BRIDGE
HOPEWELL
BAILE
RT. 10
GRAVELLY RUN
RT. 10
BAILEY CR
SEWAGE TREATMENT PLANT
RT. 156

A

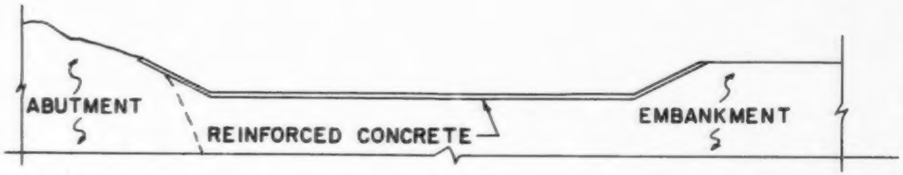

IVER
JORDAN POINT
BAILEY BAY
ILEY CREEK
SCALE IN FEET
2000
0
2000
4000

HOPEWELL, VIRGINIA
KEPONE STUDY
ALTERNATIVE 12
NORFOLK DISTRICT
CORPS OF ENGINEERS

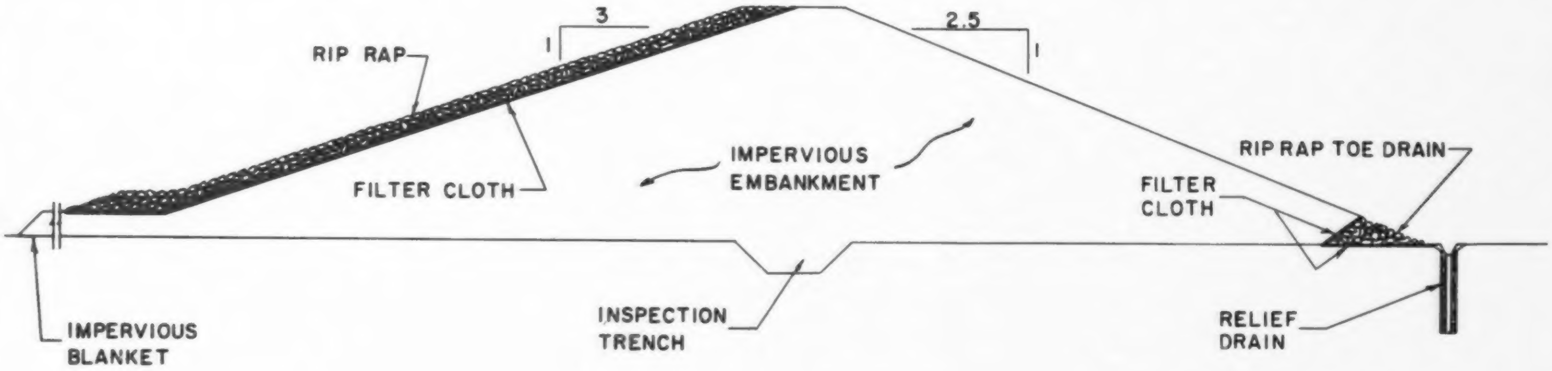
OCTOBER 1977

B

PLATE 28

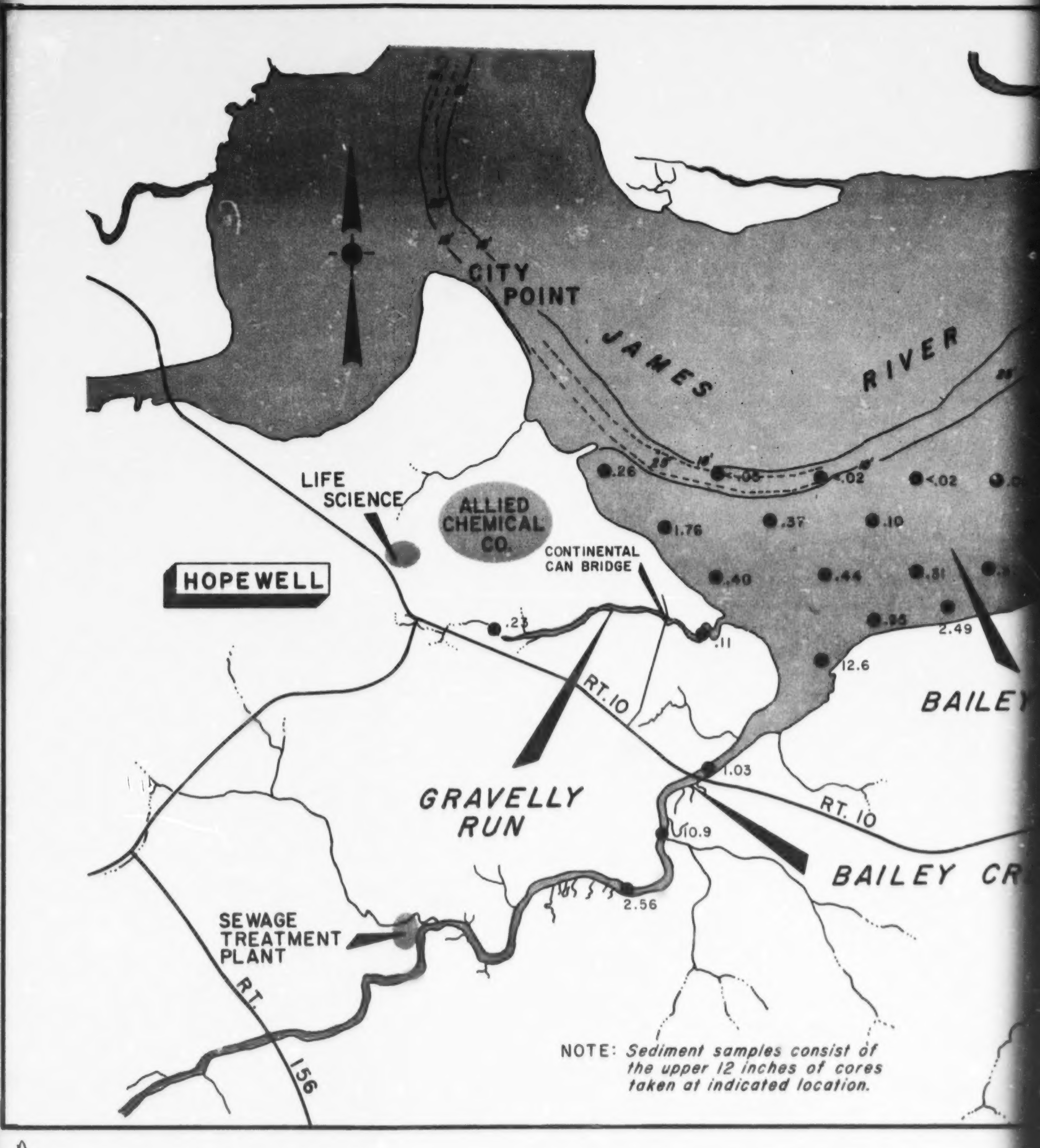

ABUTMENT
REINFORCED CONCRETE
EMBANKMENT

SPILLWAY


RIP RAP
1
3
2.5
1
FILTER CLOTH
IMPERVIOUS EMBANKMENT
RIP RAP TOE DRAIN
FILTER CLOTH
IMPERVIOUS BLANKET
INSPECTION TRENCH
RELIEF DRAIN

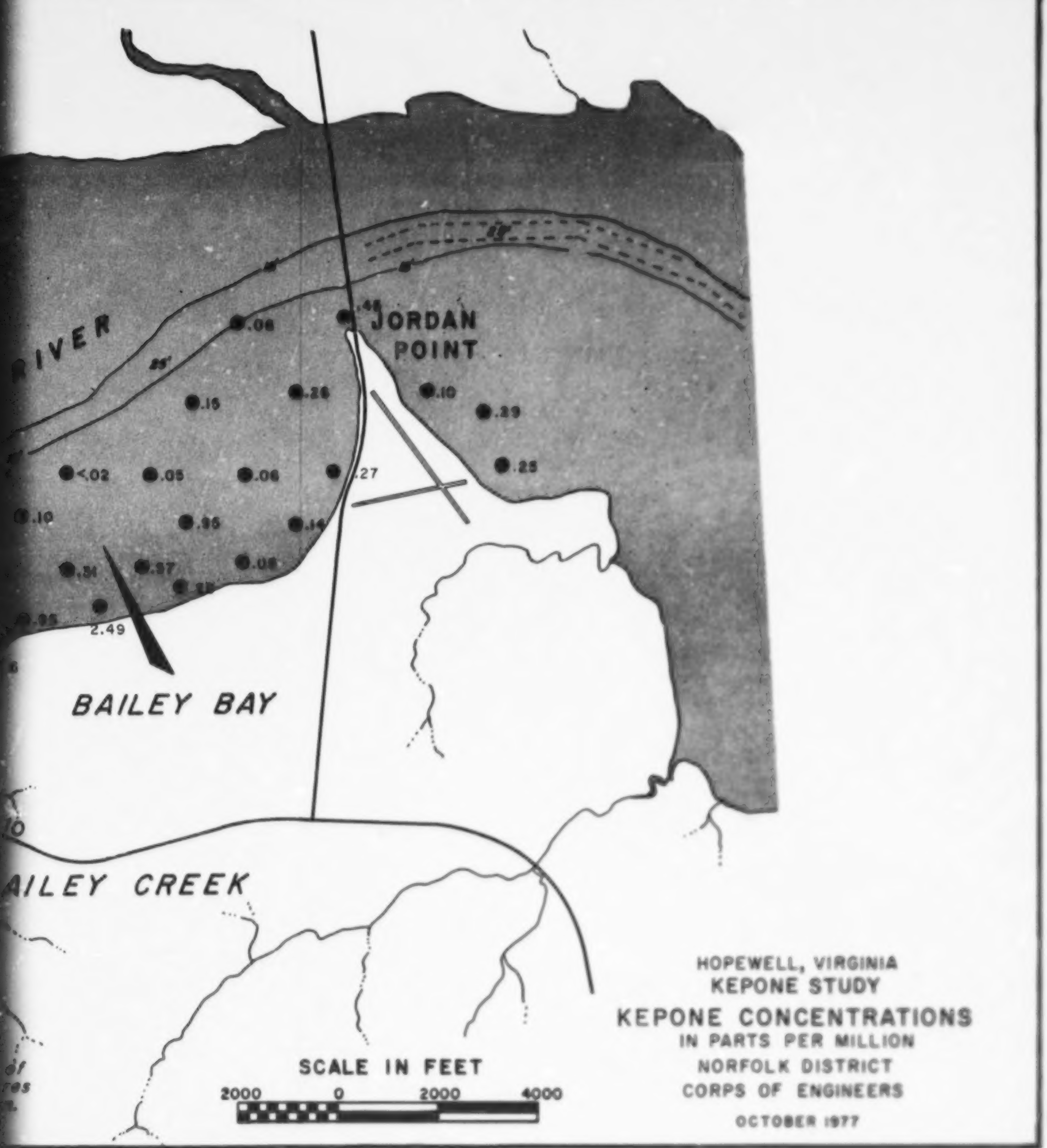
DAM

HOPEWELL, VIRGINIA
KEPONE STUDY
DAM UPSTREAM
RT. 156 BRIDGE
TYPICAL SECTIONS
NORFOLK DISTRICT
CORPS OF ENGINEERS
OCTOBER 1977


CITY POINT
JAMES RIVER
LIFE SCIENCE
ALLIED CHEMICAL CO.
CONTINENTAL CAN BRIDGE
HOPEWELL
.26
<.05
<.02
<.02
1.76
.37
.10
.40
.44
.81
.35
2.49
12.6
.23
.11
1.03
10.9
2.56
RT. 10
RT. 10
BAILEY
GRAVELLY RUN
BAILEY CR
SEWAGE TREATMENT PLANT
RT. 156

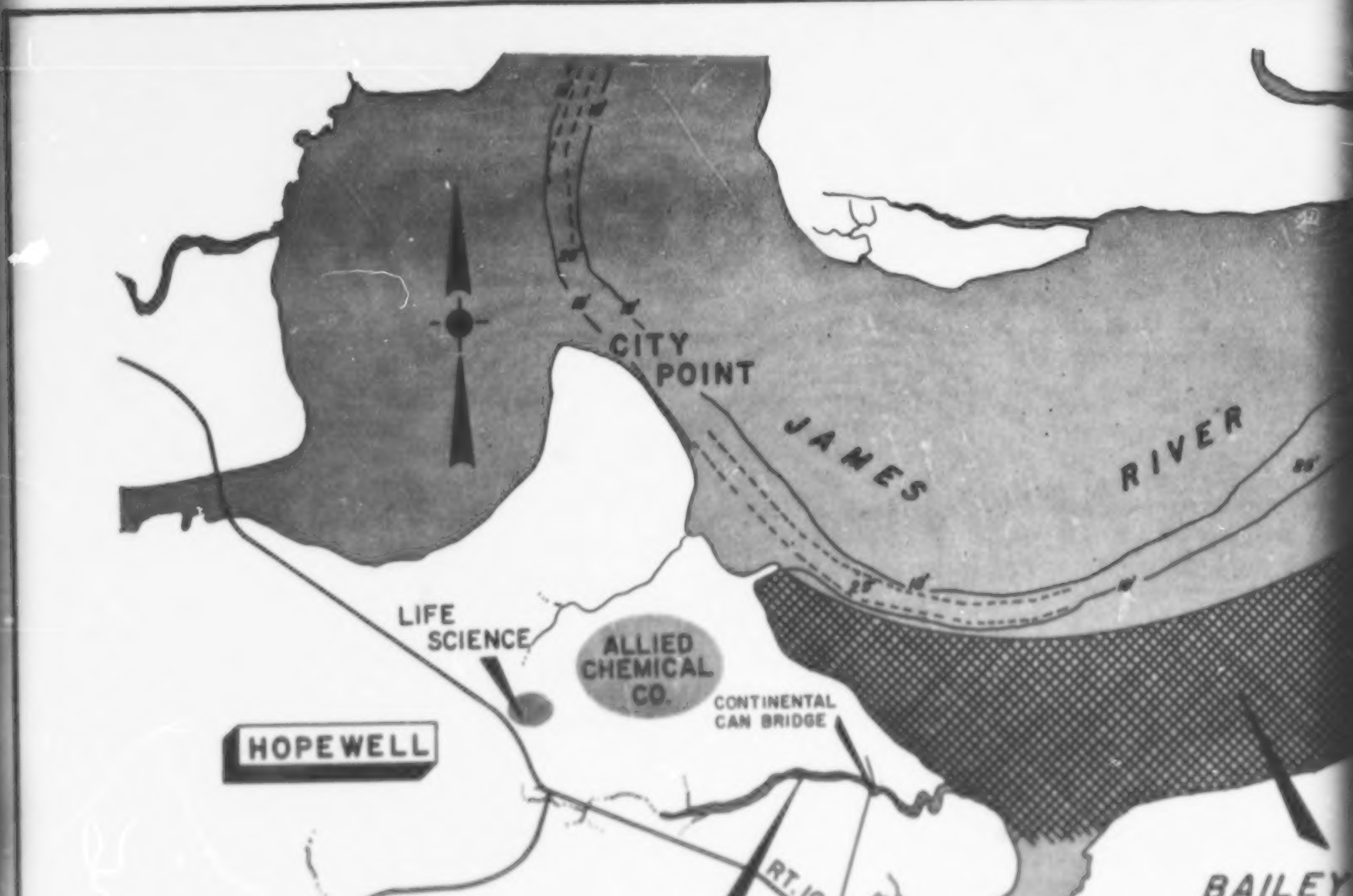
NOTE: *Sediment samples consist of the upper 12 inches of cores taken at indicated location.*

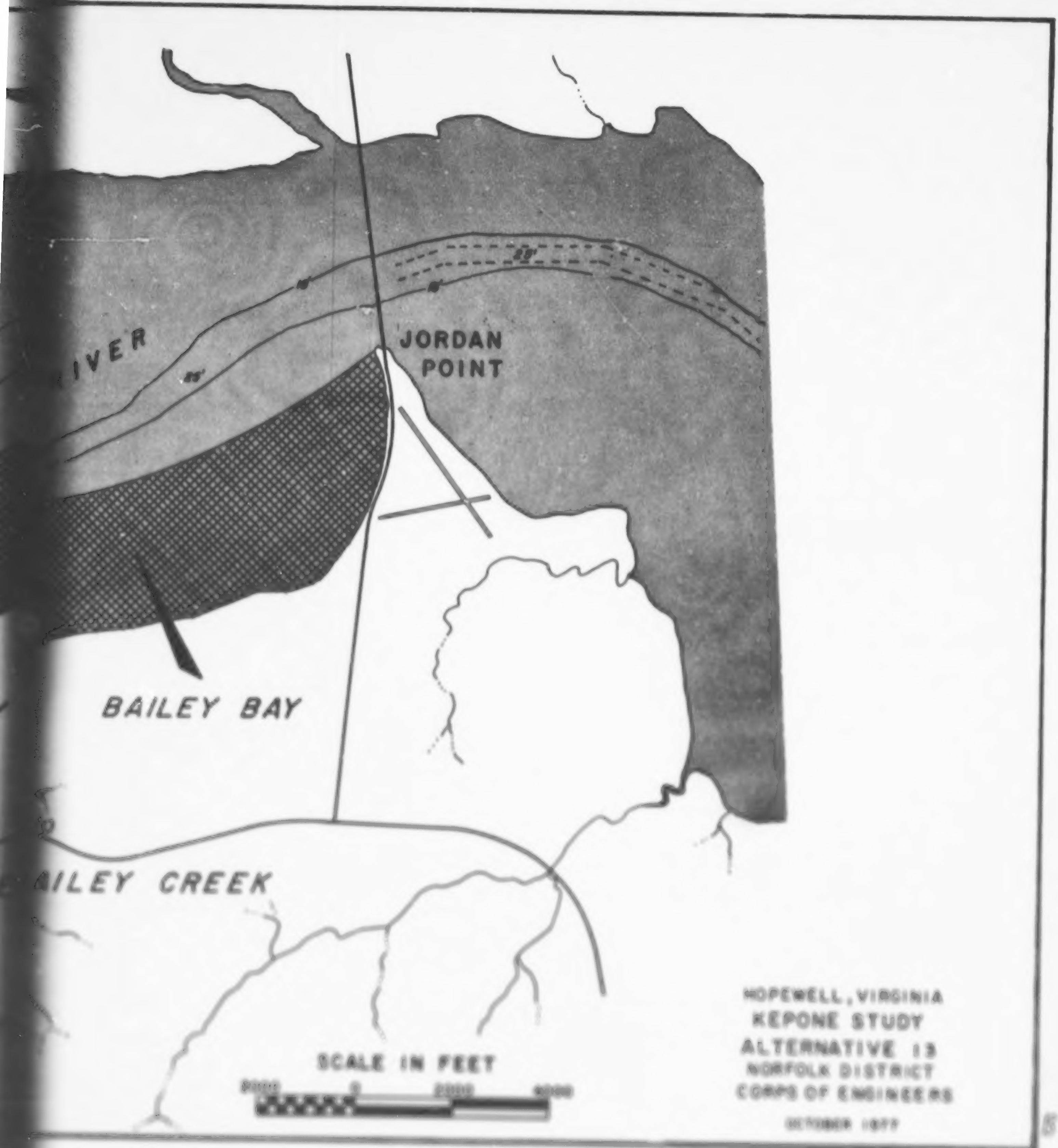
A


RIVER
25'
25'
25'
.48
JORDAN POINT
.06
.15
.26
.10
.29
<.02
.05
.06
.27
.25
.10
.35
.14
.31
.37
.08
.35
2.49
BAILEY BAY
10
AILEY CREEK
SCALE IN FEET
2000
0
2000
4000

HOPEWELL, VIRGINIA
KEPONE STUDY
KEPONE CONCENTRATIONS
IN PARTS PER MILLION
NORFOLK DISTRICT
CORPS OF ENGINEERS
OCTOBER 1977

8

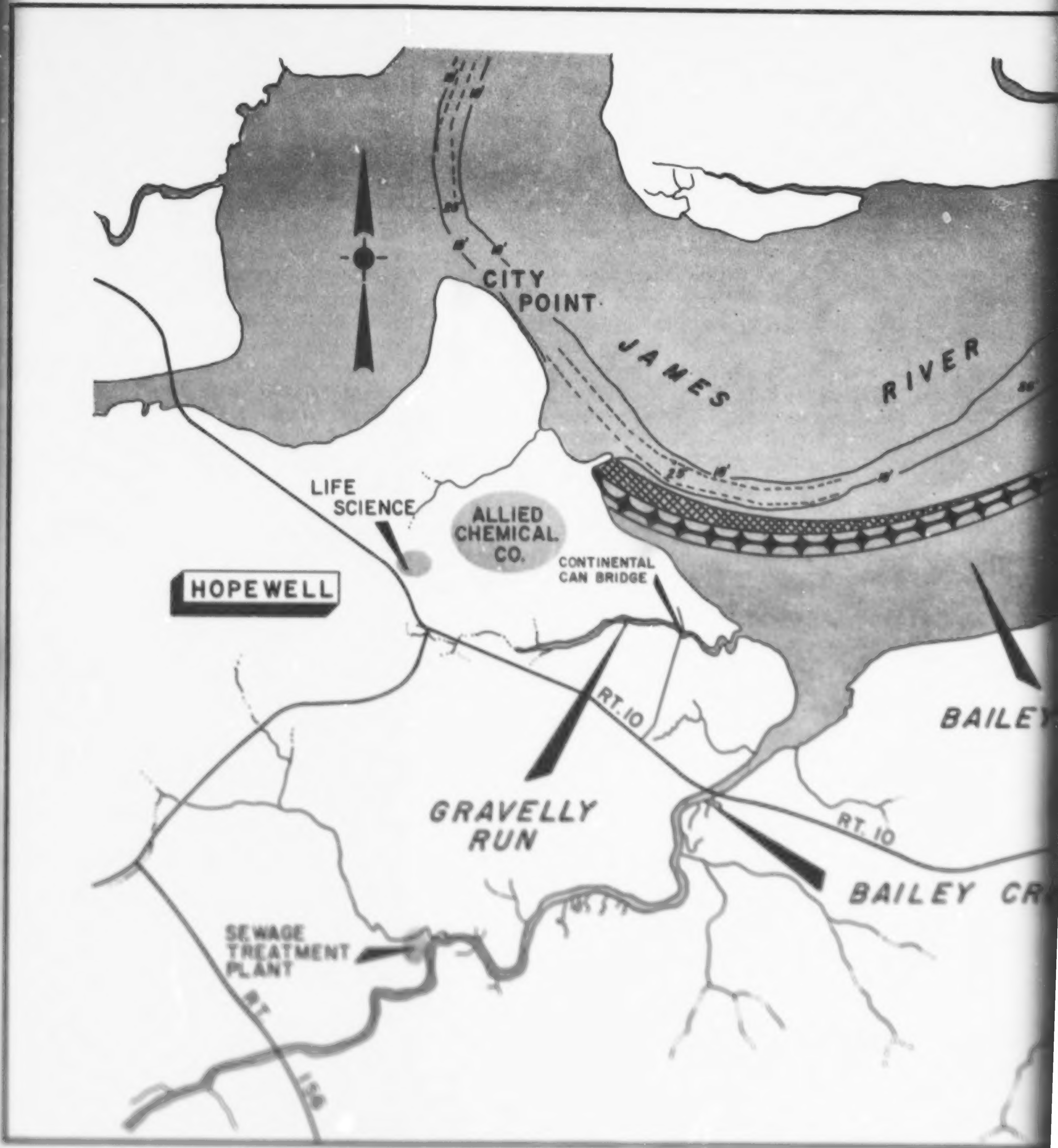

CITY POINT
JAMES RIVER
LIFE SCIENCE
ALLIED CHEMICAL CO.
CONTINENTAL CAN BRIDGE
HOPEWELL
RT. 10
BAILEY
GRAVELLY RUN
RT. 10
BAILEY CRE
SEWAGE TREATMENT PLANT
RT. 156

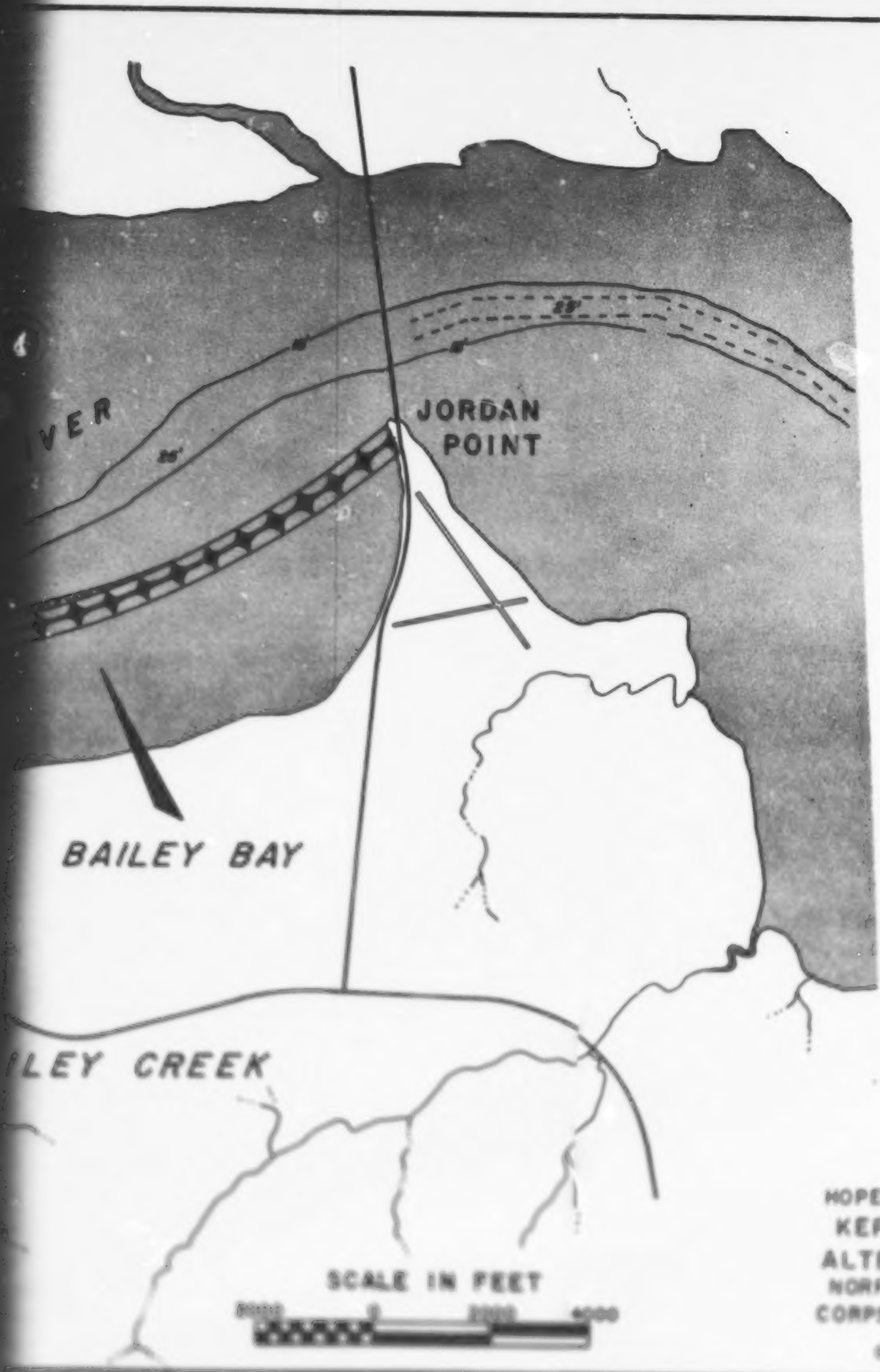


RIVER
28'
25'
JORDAN POINT
BAILEY BAY
BAILEY CREEK
SCALE IN FEET
2000
0
2000
4000

HOPEWELL, VIRGINIA
KEPONE STUDY
ALTERNATIVE 13
NORFOLK DISTRICT
CORPS OF ENGINEERS

OCTOBER 1977

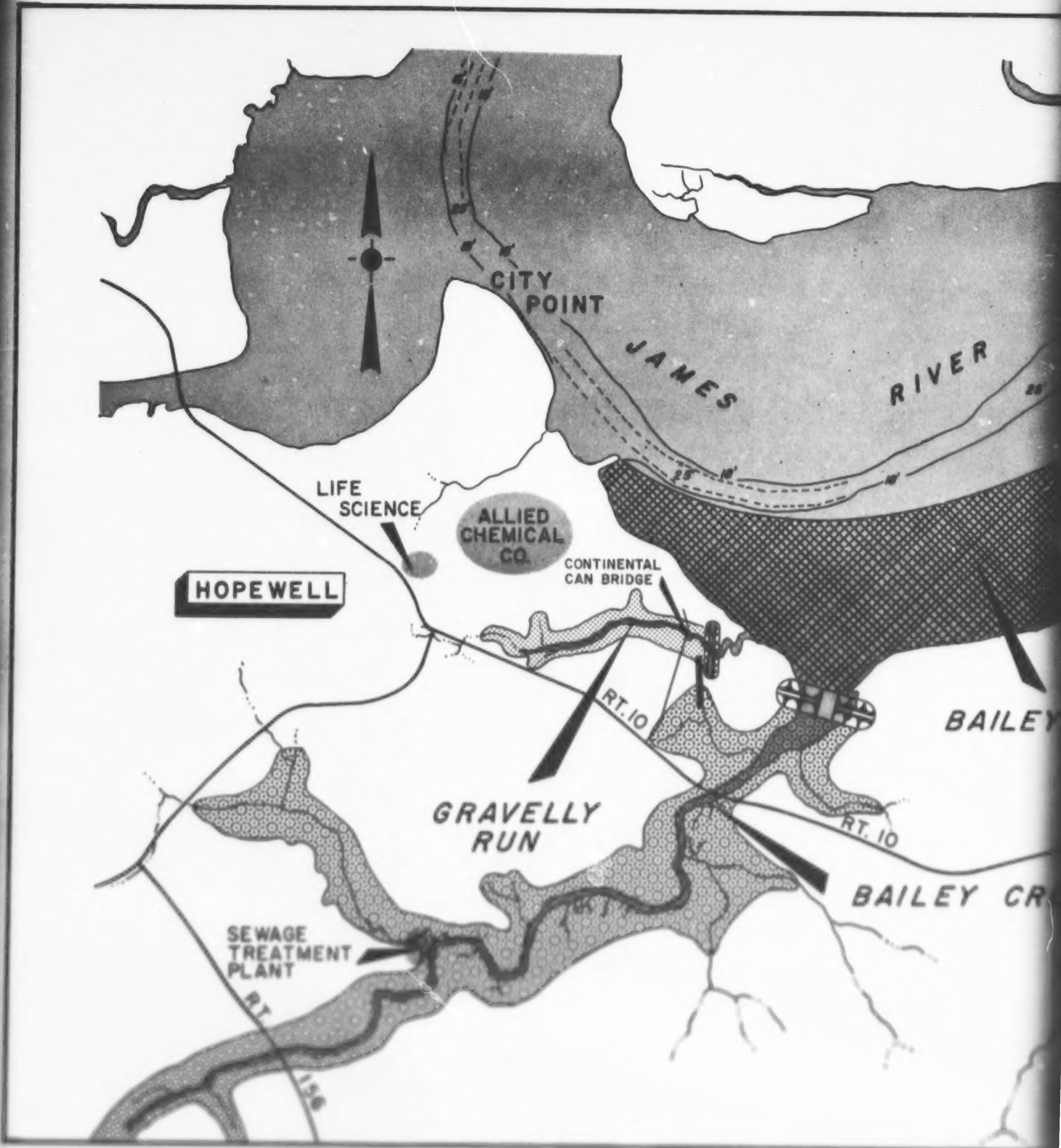

CITY POINT
JAMES RIVER
LIFE SCIENCE
ALLIED CHEMICAL CO.
CONTINENTAL CAN BRIDGE
HOPEWELL
RT. 10
BAILEY
GRAVELLY RUN
RT. 10
BAILEY CR
SEWAGE TREATMENT PLANT
RT 156

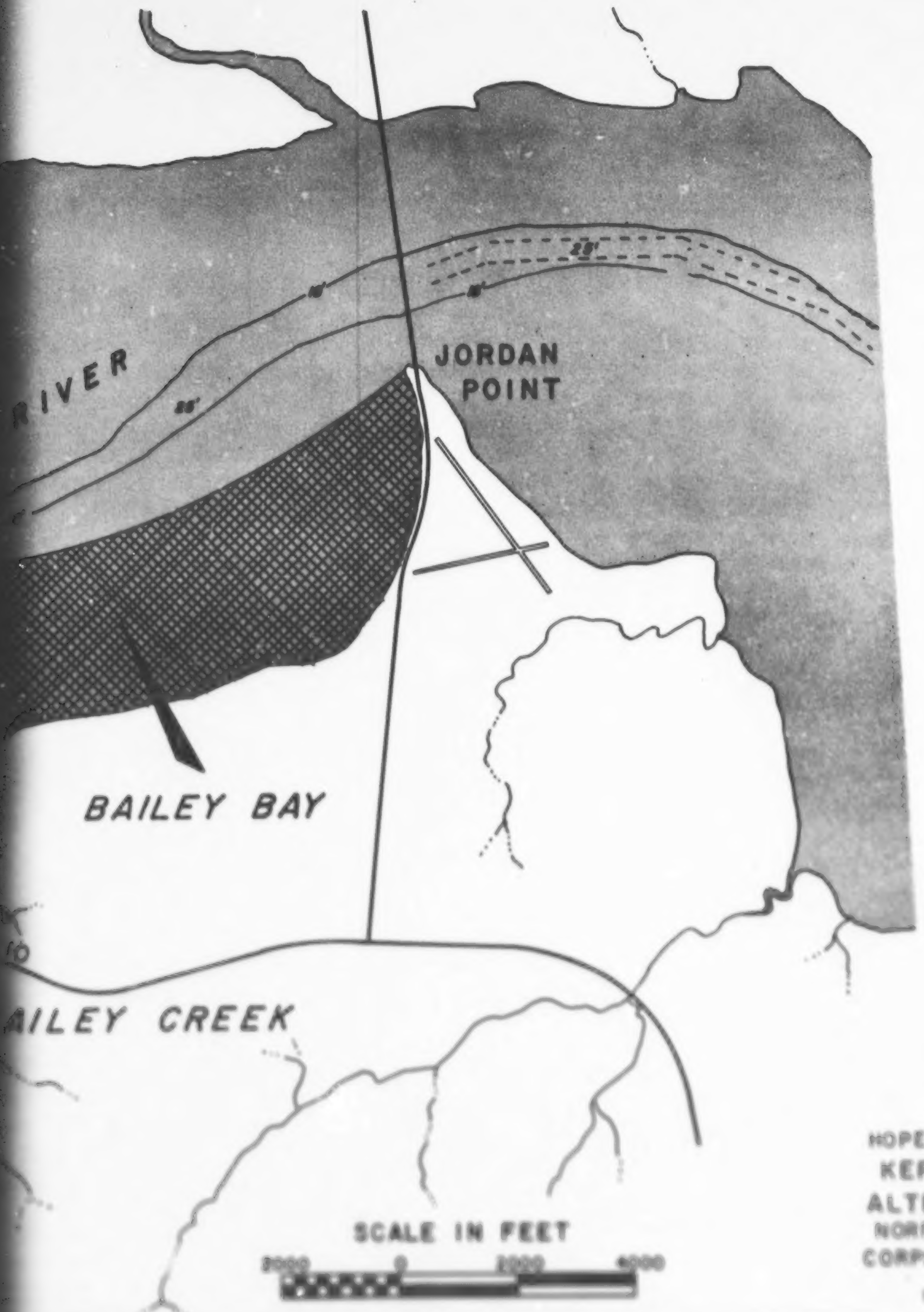

VER
JORDAN POINT
28'
25'
BAILEY BAY
ILEY CREEK
SCALE IN FEET
2000
0
2000
4000

HOPEWELL, VIRGINIA
KEPONE STUDY
ALTERNATIVE 14
NORFOLK DISTRICT
CORPS OF ENGINEERS

OCTOBER 1977

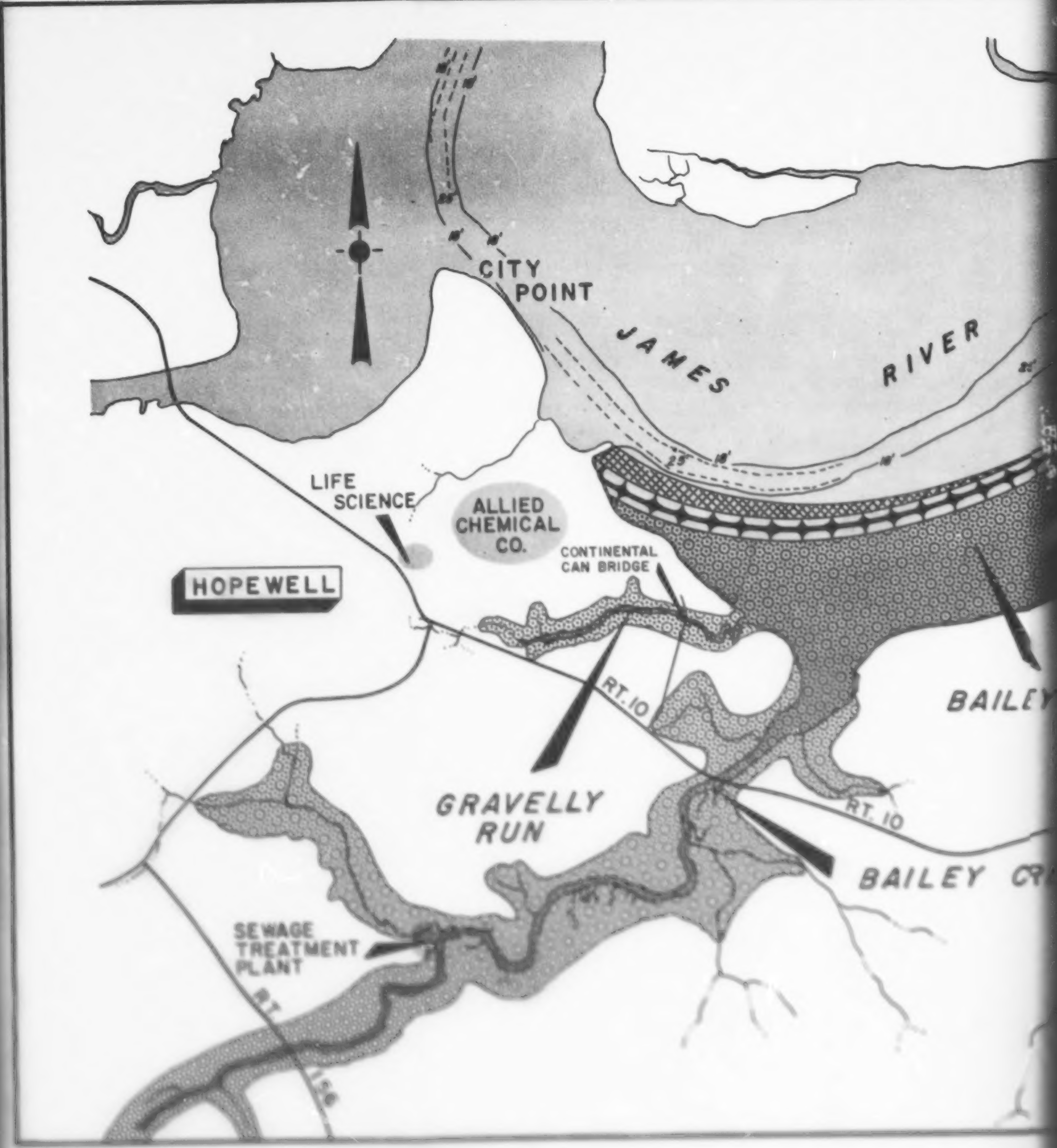
B

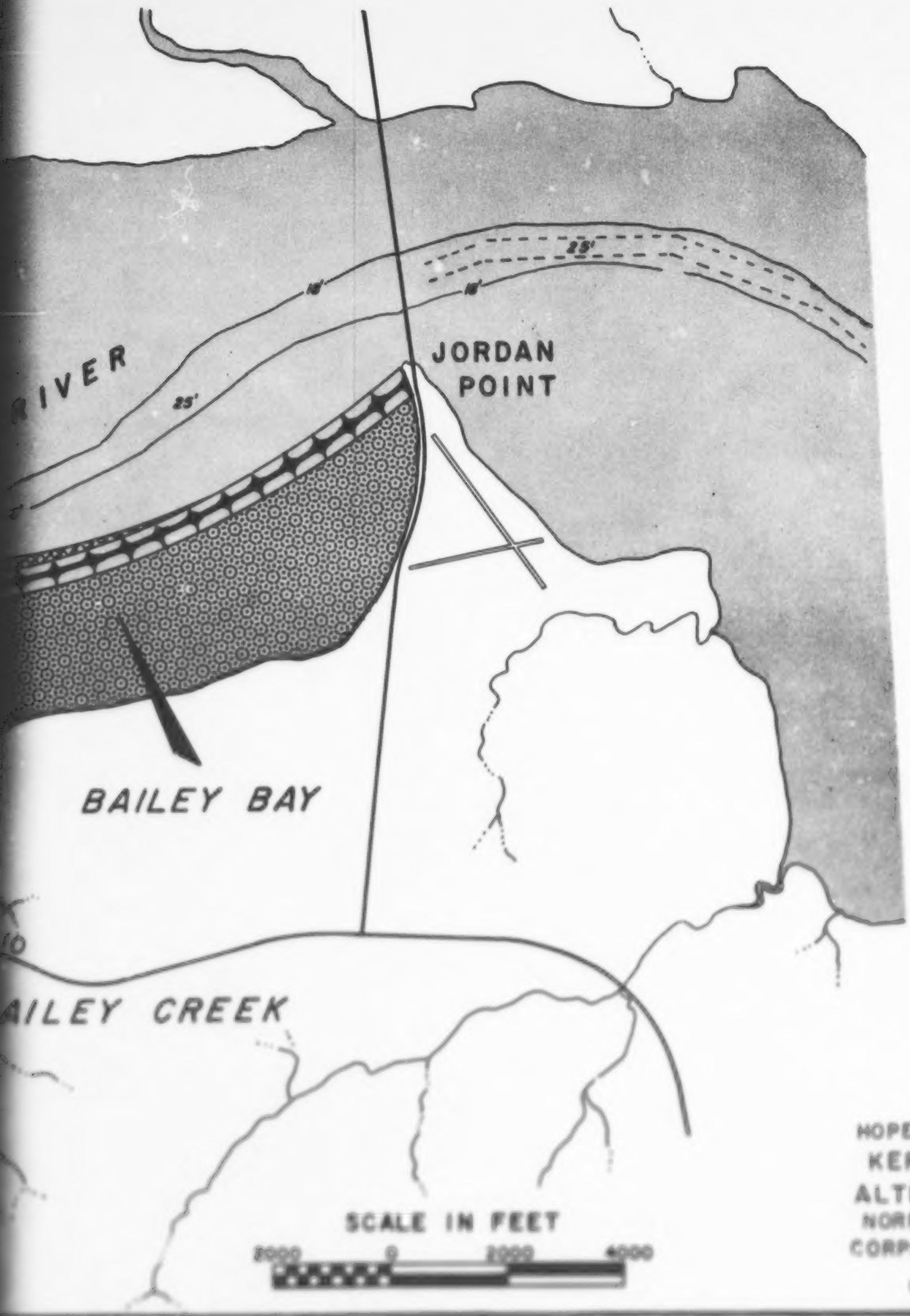

CITY POINT
JAMES RIVER
LIFE SCIENCE
ALLIED CHEMICAL CO.
HOPEWELL
CONTINENTAL CAN BRIDGE
RT. 10
BAILEY
GRAVELLY RUN
RT. 10
BAILEY CR
SEWAGE TREATMENT PLANT
RT. 156
25'
18'


RIVER
25'
JORDAN POINT
BAILEY BAY
AILEY CREEK
SCALE IN FEET
2000 0 2000 4000

HOPEWELL, VIRGINIA
KEPONE STUDY
ALTERNATIVE 15
NORFOLK DISTRICT
CORPS OF ENGINEERS

OCTOBER 1977

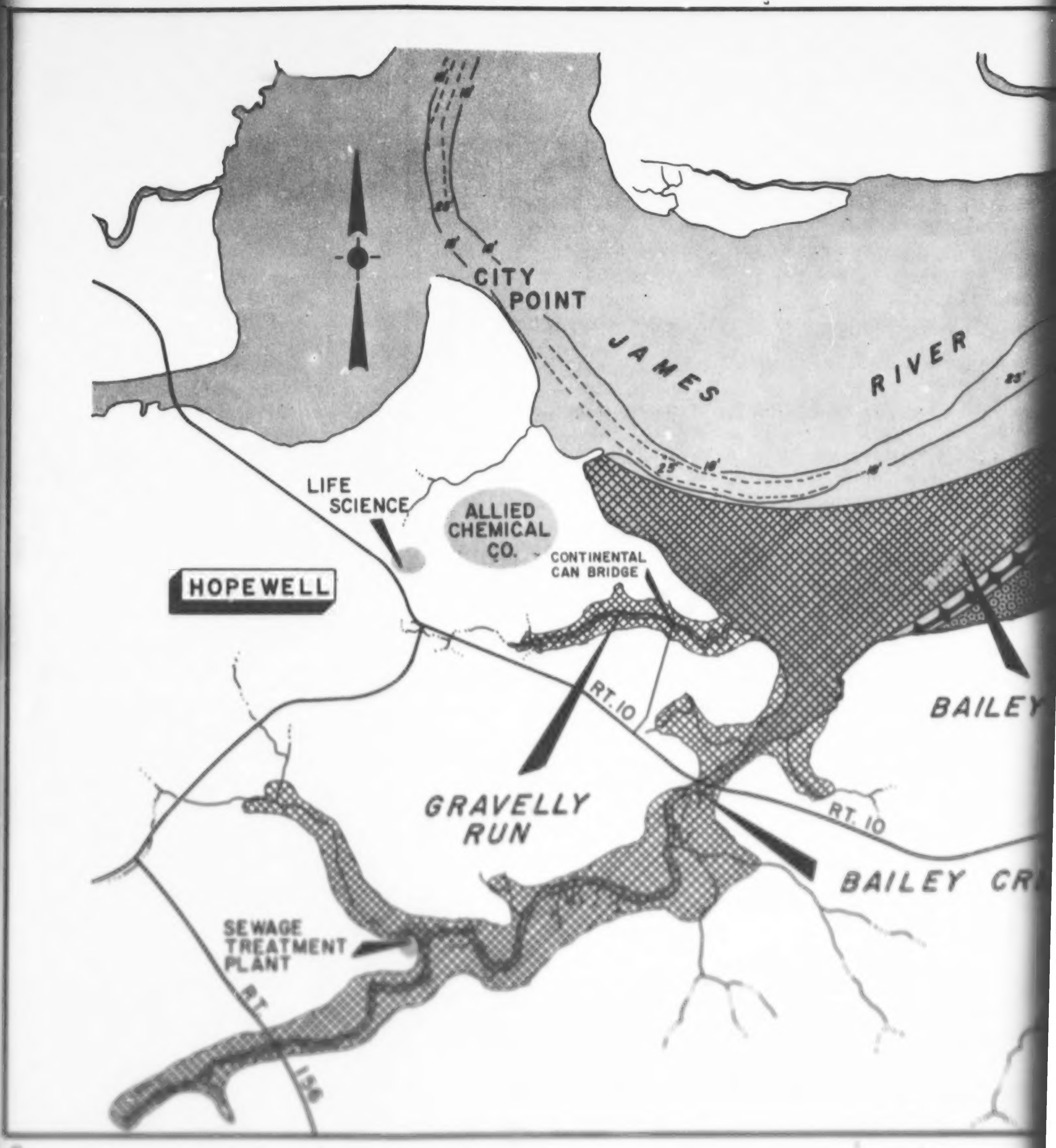

CITY POINT
JAMES RIVER
25'
18'
20'
LIFE SCIENCE
ALLIED CHEMICAL CO.
CONTINENTAL CAN BRIDGE
HOPEWELL
RT. 10
RT. 10
BAILE
GRAVELLY RUN
BAILEY CR
SEWAGE TREATMENT PLANT
RT. 156


RIVER
25'
18'
25'
18'
JORDAN POINT
BAILEY BAY
10
AILEY CREEK
SCALE IN FEET
2000
0
2000
4000

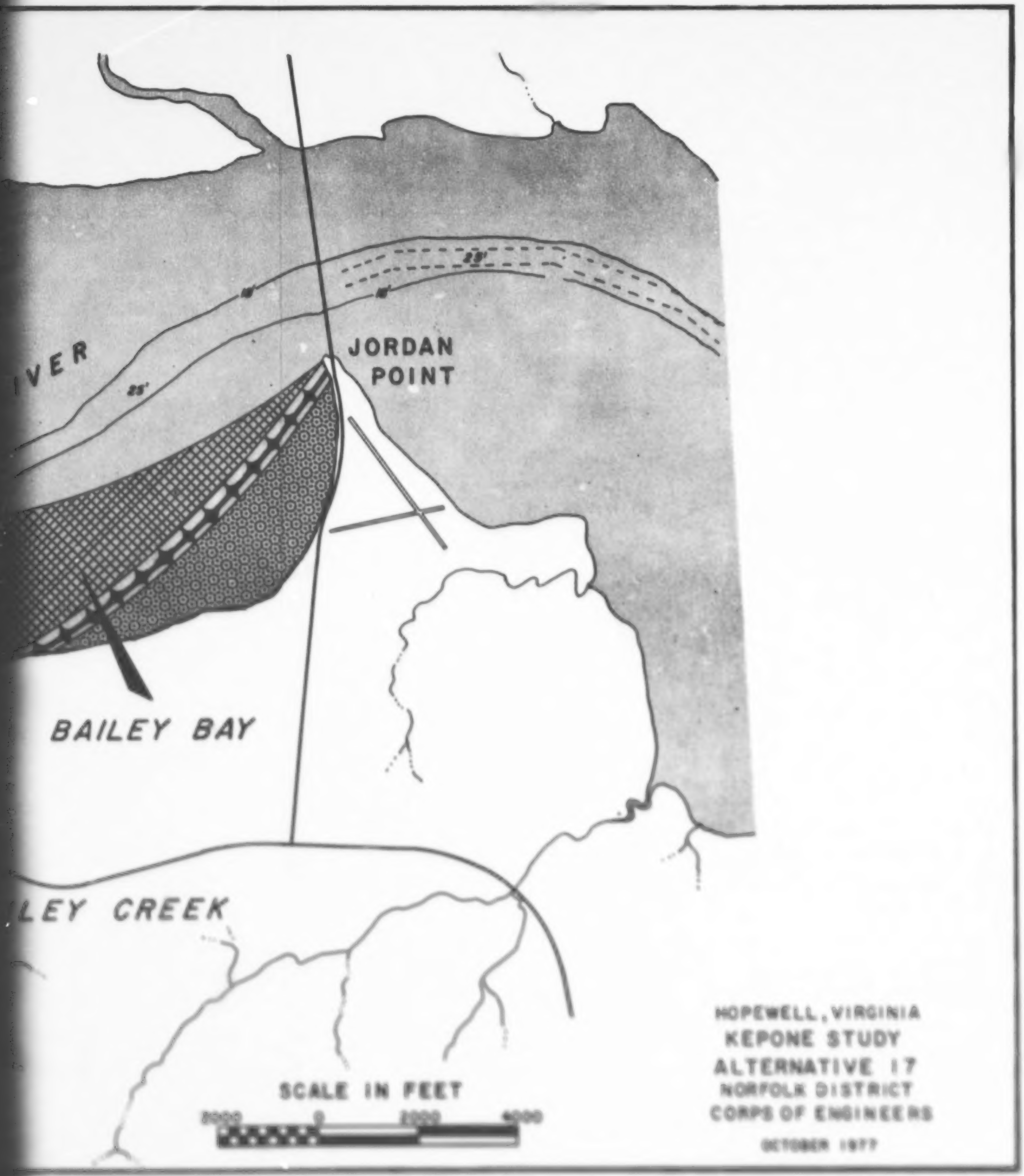
HOPEWELL, VIRGINIA
KEPONE STUDY
ALTERNATIVE 16
NORFOLK DISTRICT
CORPS OF ENGINEERS

OCTOBER 1977

E


CITY POINT
JAMES RIVER
25'
18'
LIFE SCIENCE
ALLIED CHEMICAL CO.
CONTINENTAL CAN BRIDGE
HOPEWELL
RT. 10
BAILEY
GRAVELLY RUN
RT. 10
BAILEY CR
SEWAGE TREATMENT PLANT
RT. 156

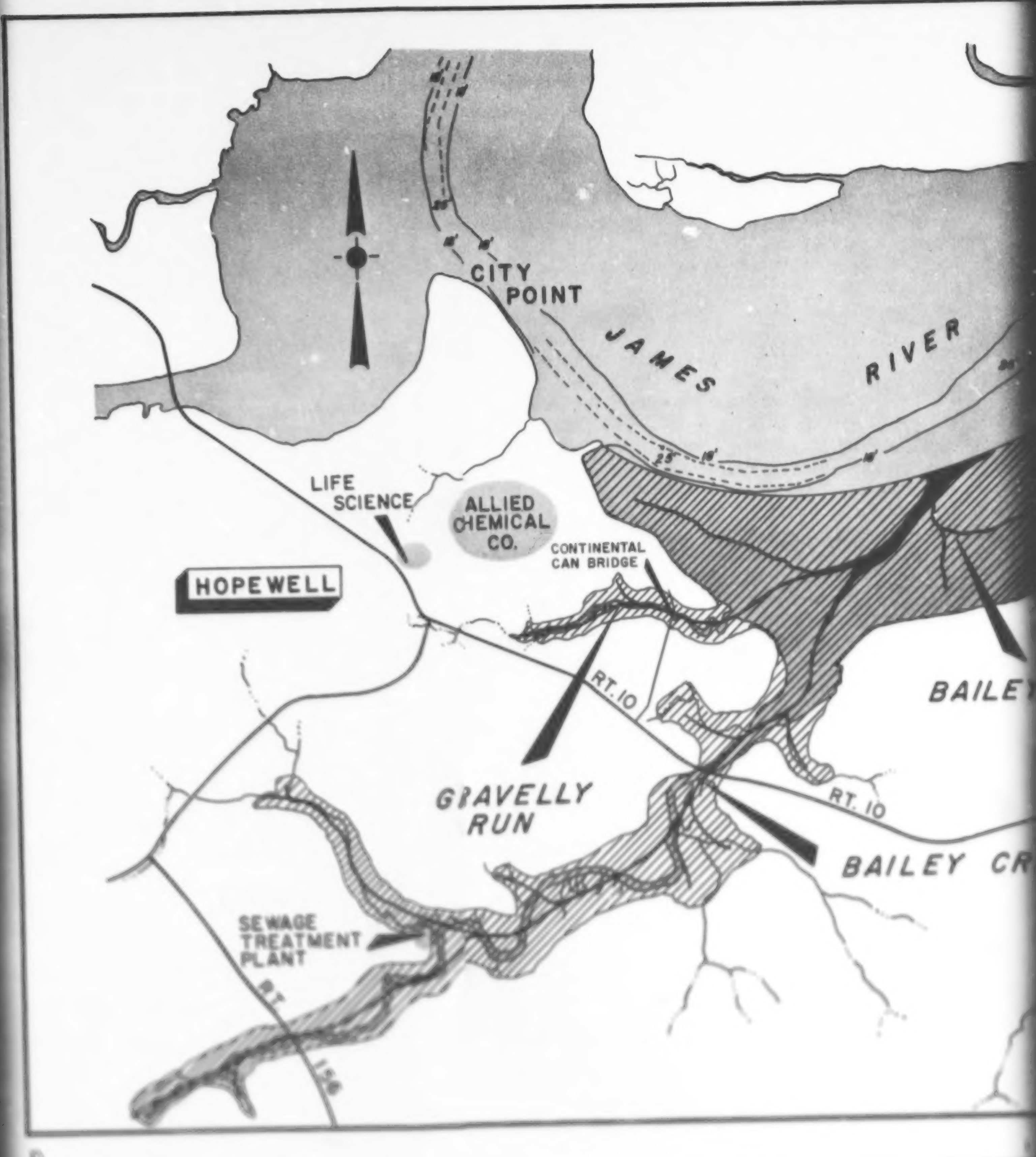
B


IVER
25'
18'
25'
18'
JORDAN POINT
BAILEY BAY
LEY CREEK
SCALE IN FEET
2000 0 2000 4000

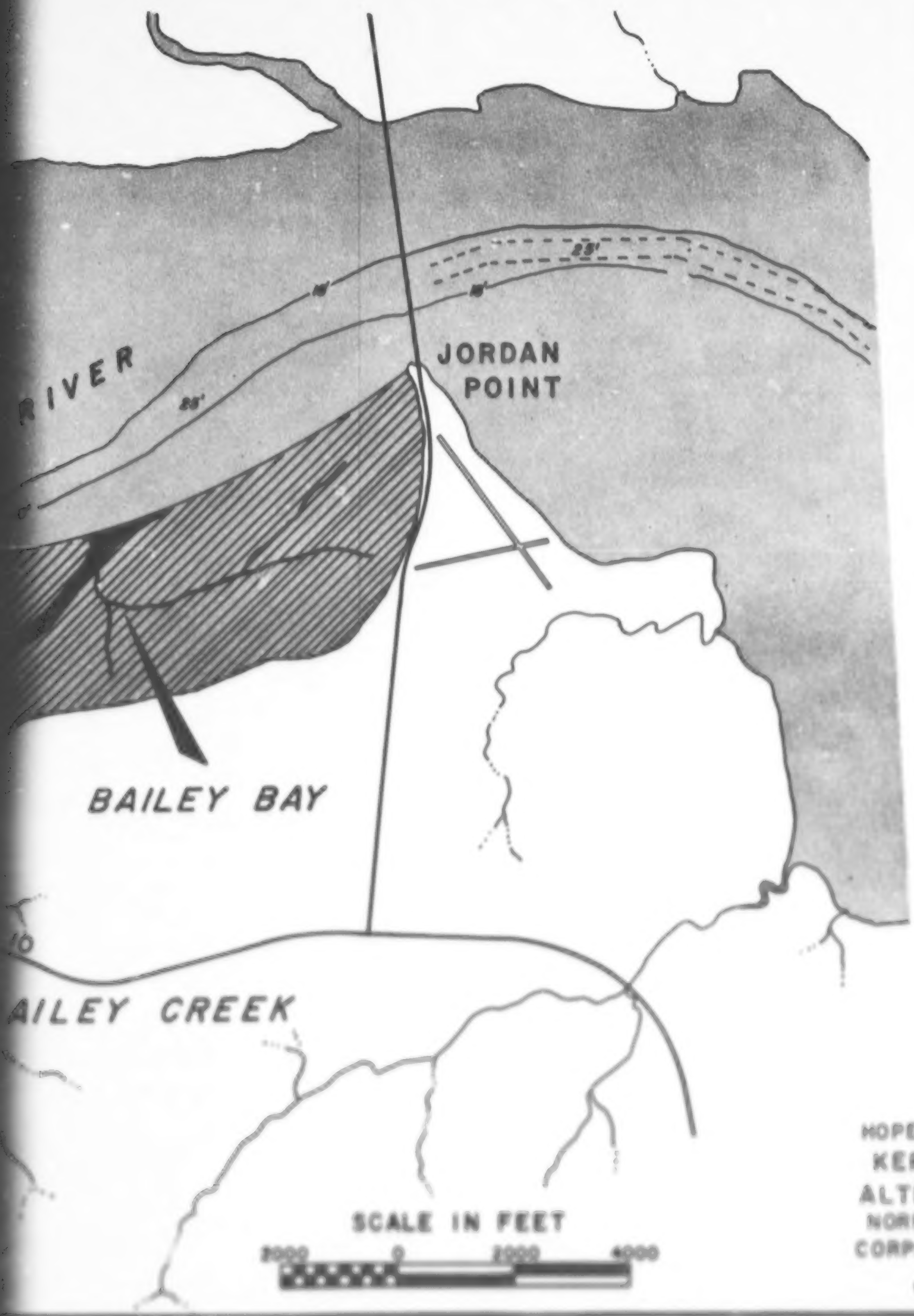
HOPEWELL, VIRGINIA
KEPONE STUDY
ALTERNATIVE 17
NORFOLK DISTRICT
CORPS OF ENGINEERS

OCTOBER 1977

PLATE 35

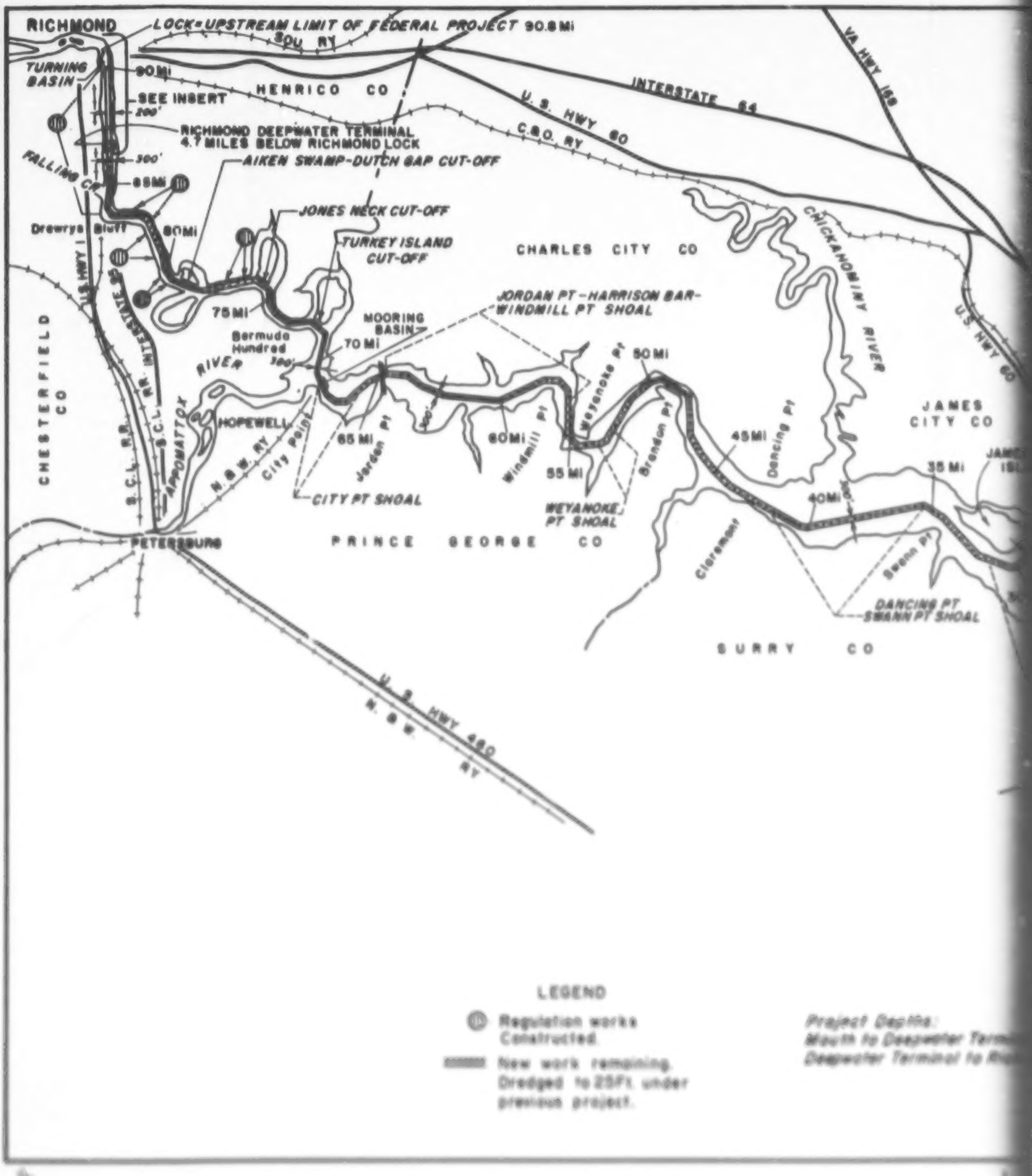

CITY POINT
JAMES RIVER
LIFE SCIENCE
ALLIED CHEMICAL CO.
CONTINENTAL CAN BRIDGE
HOPEWELL
RT. 10
BAILE
GRAVELLY RUN
RT. 10
BAILEY CR
SEWAGE TREATMENT PLANT
RT. 156
25'
18'

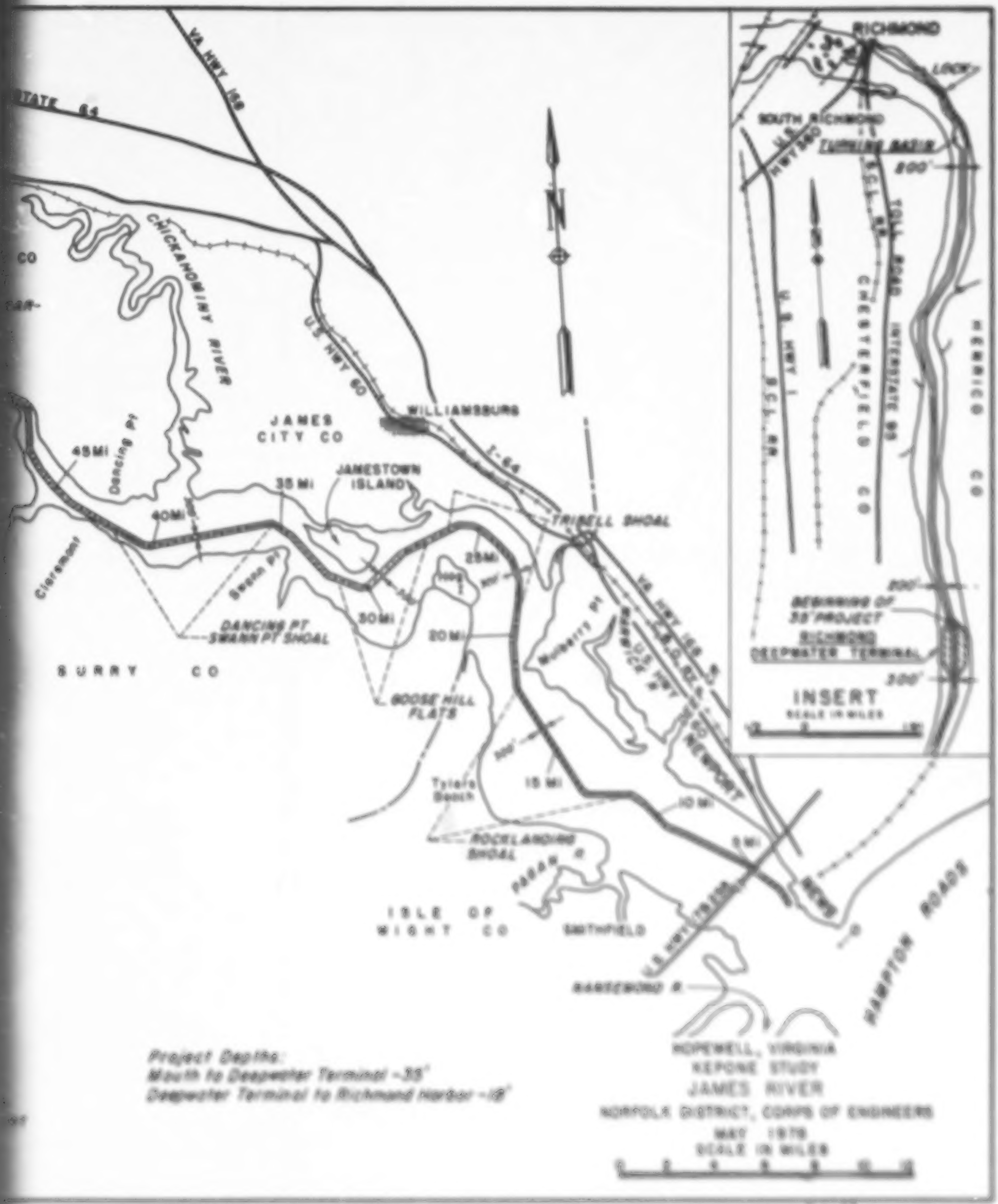
A


RIVER
25'
18'
18'
25'
0'
JORDAN POINT
BAILEY BAY
10
AILEY CREEK
SCALE IN FEET
2000
0
2000
4000

HOPEWELL, VIRGINIA
KEPONE STUDY
ALTERNATIVE 18
NORFOLK DISTRICT
CORPS OF ENGINEERS

OCTOBER 1977

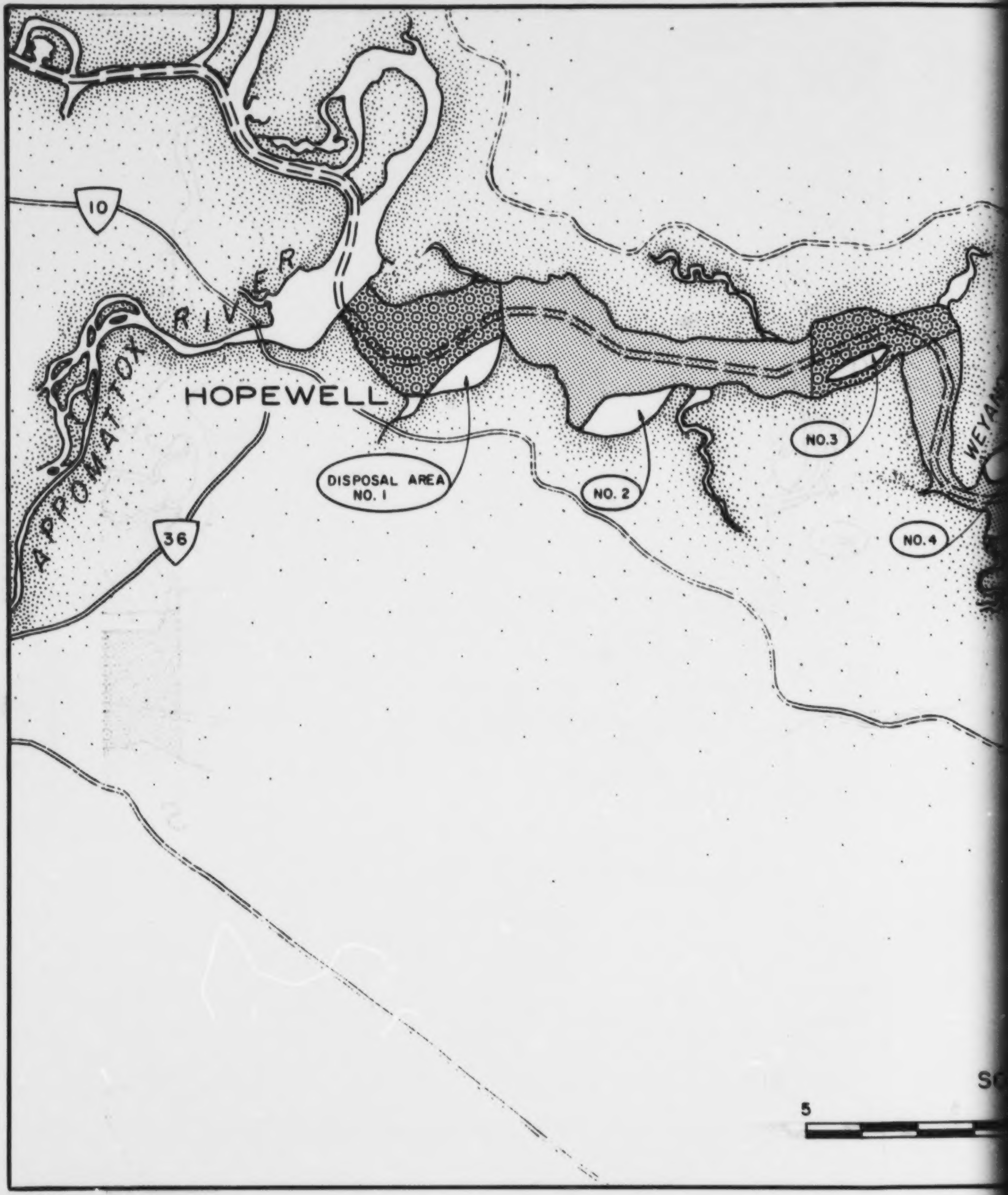

RICHMOND
LOCK=UPSTREAM LIMIT OF FEDERAL PROJECT 90.8 MI
SOU RY
TURNING BASIN
90 MI
SEE INSERT
200'
HENRICO CO
INTERSTATE 64
VA HWY 156
U.S. HWY 60
C.& O. RY
RICHMOND DEEPWATER TERMINAL 4.7 MILES BELOW RICHMOND LOCK
300'
AIKEN SWAMP-DUTCH GAP CUT-OFF
FALLING CR
85 MI
JONES NECK CUT-OFF
Drewrys Bluff
80 MI
TURKEY ISLAND CUT-OFF
CHARLES CITY CO
CHICKAHOMINY RIVER
JORDAN PT-HARRISON BAR-WINDMILL PT SHOAL
US HWY 1
INTERSTATE 95
75 MI
MOORING BASIN
Bermuda Hundred
70 MI
300'
RIVER
CHESTERFIELD CO
S.C.L. RR
RR
S.C.L.
APPOMATTOX
HOPEWELL
N.& W. RY
City Point
65 MI
Jordan Pt
300'
60 MI
Windmill Pt
Weyanoke Pt
50 MI
Brandon Pt
55 MI
45 MI
Dancing Pt
JAMES CITY CO
35 MI
CITY PT SHOAL
WEYANOKE PT SHOAL
40 MI
300'
PETERSBURG
PRINCE GEORGE CO
Claremont
Swann Pt
DANCING PT SWANN PT SHOAL
SURRY CO
U.S. HWY 460
N.& W. RY
LEGEND
Regulation works Constructed.
New work remaining. Dredged to 25 Ft. under previous project.
Project Depths:
Mouth to Deepwater Term
Deepwater Terminal to Ri



INTERSTATE 64
VA HWY 168
CHICKAHOMINY RIVER
CO
U.S. HWY 60
WILLIAMSBURG
JAMES CITY CO
N
I-64
JAMESTOWN ISLAND
TRIBELL SHOAL
45MI
40MI
35MI
30MI
25MI
20MI
15MI
10MI
5MI
Dancing Pt
Claremont
Swann Pt
DANCING PT SWANN PT SHOAL
SURRY CO
GOOSE HILL FLATS
Mulberry Pt
VA HWY 168
U.S. HWY 60
NEWPORT NEWS
Tylers Beach
ROCKLANDING SHOAL
PAGAN R.
ISLE OF WIGHT CO
SMITHFIELD
U.S. HWY 17
BARSEBORO R.
HAMPTON ROADS
RICHMOND
LOCK
SOUTH RICHMOND
U.S. HWY 360
TURNING BASIN
200'
S.C.L. RR
TOLL ROAD
U.S. HWY 1
S.C.L. RR
CHESTERFIELD CO
INTERSTATE 95
HENRICO CO
200'
BEGINNING OF 35' PROJECT
RICHMOND DEEPWATER TERMINAL
300'
INSERT
SCALE IN MILES

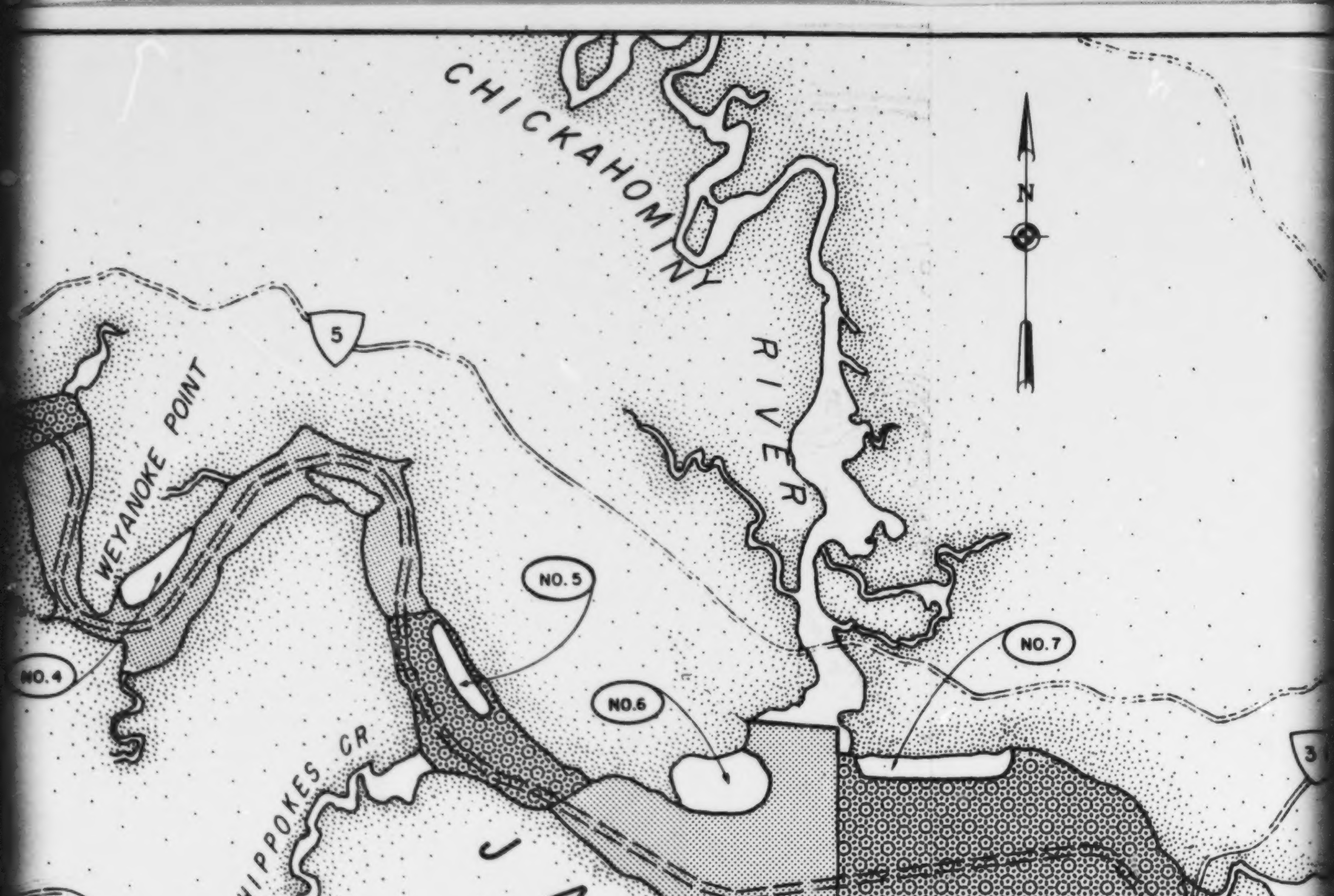
Project Depths:
Mouth to Deepwater Terminal -35'
Deepwater Terminal to Richmond Harbor -18'

HOPEWELL, VIRGINIA
KEPONE STUDY
JAMES RIVER
NORFOLK DISTRICT, CORPS OF ENGINEERS
MAY 1978
SCALE IN MILES

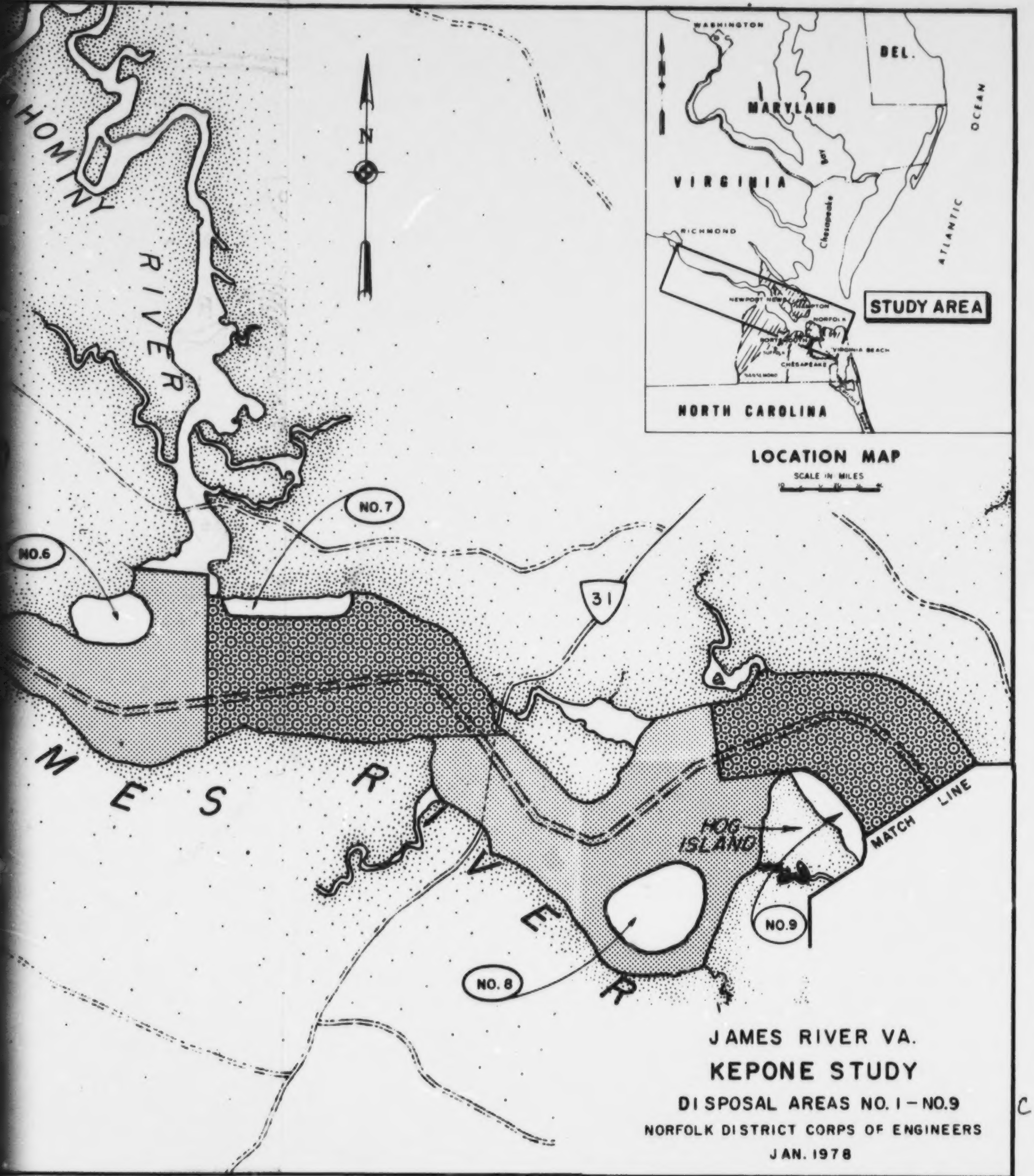

10
APPOMATTOX RIVER
HOPEWELL
36
DISPOSAL AREA NO. 1
NO. 2
NO.3
NO.4
WEYAN
SC
5

A

1


CHICKAHOMINY RIVER
N
5
WEYANOKE POINT
NO. 5
NO. 4
NO. 6
NO. 7
CHIPPOKES CR.
JAMES RIVER
31
NO. 8
SCALE IN MILES
0
5

1 B


CHICKAHOMINY RIVER
N
WASHINGTON
DEL.
MARYLAND
OCEAN
VIRGINIA
Chesapeake Bay
ATLANTIC
RICHMOND
STUDY AREA
NEWPORT NEWS
HAMPTON
NORFOLK
PORTSMOUTH
VIRGINIA BEACH
CHESAPEAKE
NORTH CAROLINA
LOCATION MAP
SCALE IN MILES
NO.7
NO.6
31
JAMES RIVER
HOG ISLAND
MATCH LINE
NO.9
NO.8

JAMES RIVER VA.

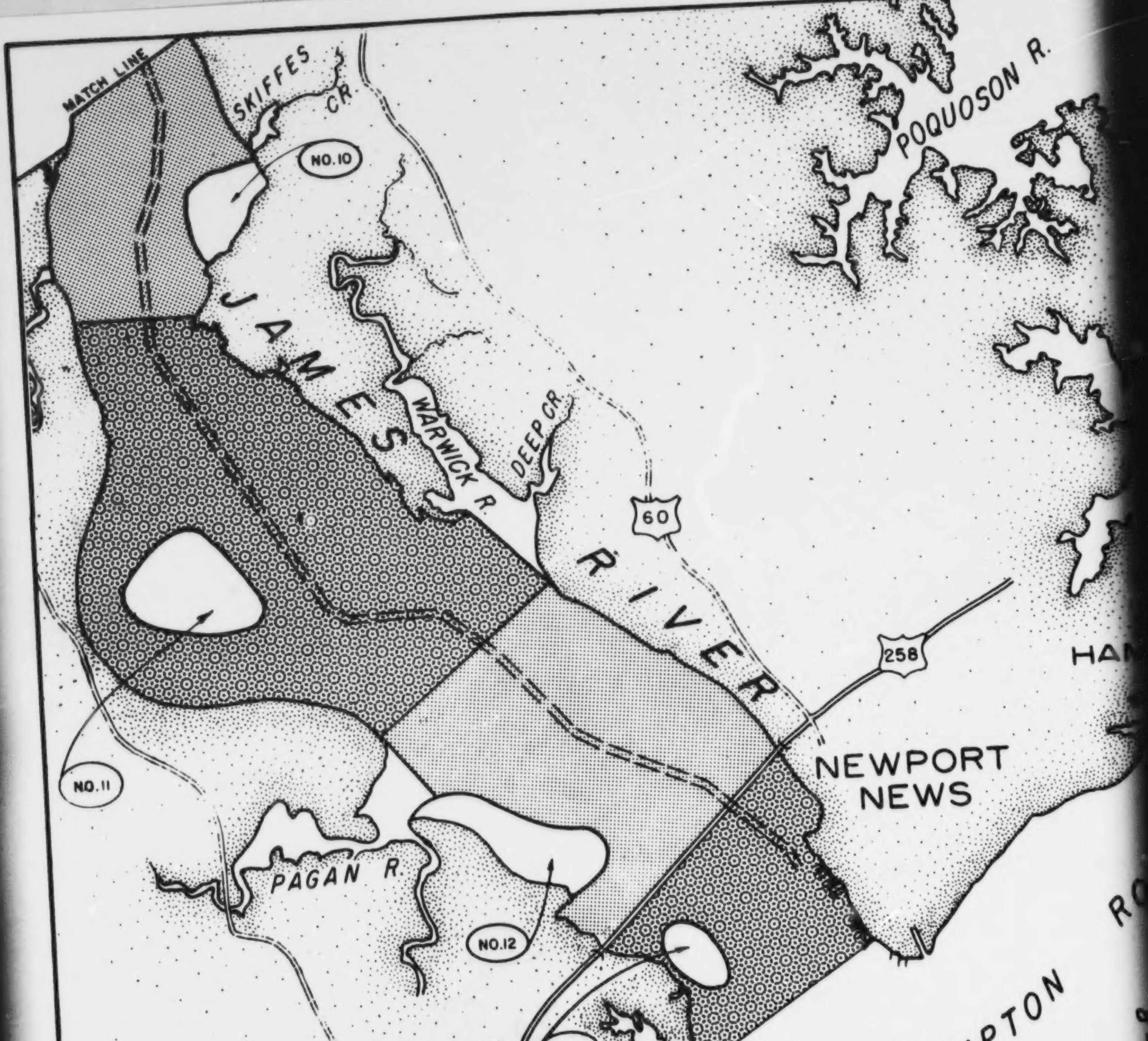
KEPONE STUDY

DISPOSAL AREAS NO. 1 – NO. 9

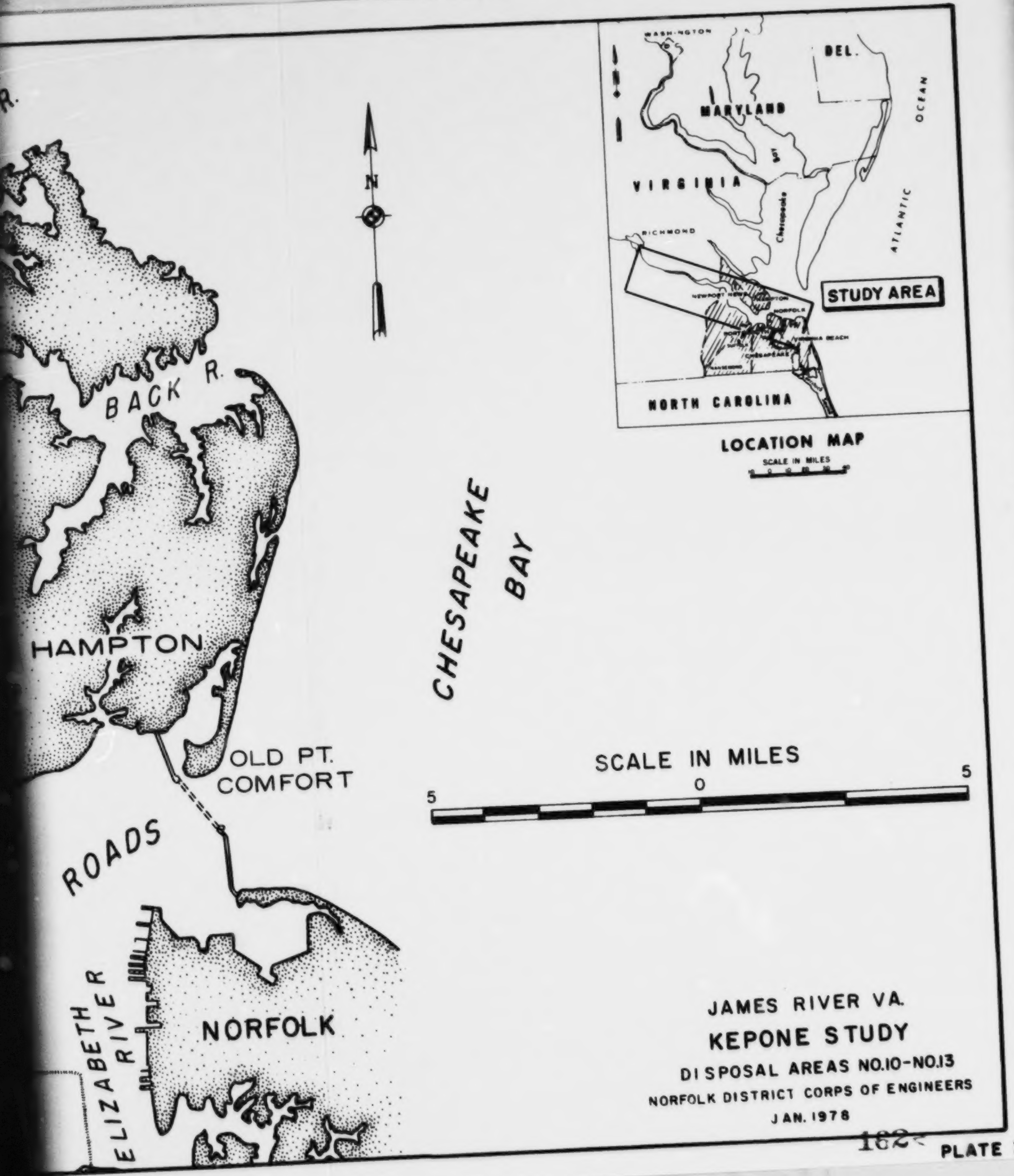
NORFOLK DISTRICT CORPS OF ENGINEERS

JAN. 1978

C


MATCH LINE
SKIFFES CR.
NO.10
POQUOSON R.
JAMES RIVER
WARWICK R.
DEEP CR.
60
258
HAM
NO.11
NEWPORT NEWS
PAGAN R.
NO.12
NO 13
17
RO
HAMPTON
NANSEMOND RIVER
BETH R.

A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BAY
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OCEAN
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RICHMOND
NEWPORT NEWS
HAMPTON
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VIRGINIA BEACH
CHESAPEAKE
STUDY AREA
NORTH CAROLINA
LOCATION MAP
SCALE IN MILES

JAMES RIVER VA.

KEPONE STUDY

DISPOSAL AREAS NO.10-NO.13

NORFOLK DISTRICT CORPS OF ENGINEERS

JAN. 1978

B

APPENDIX B

THE EPA KEPONE MITIGATION FEASIBILITY PROJECT REPORT

REMEDIAL CONVENTIONAL MEASURES
FOR
CAPTURING, STABILIZING OR
REMOVING KEPONE
IN
BAILEY BAY, BAILEY CREEK,
GRAVELLY RUN, AND
JAMES RIVER, VIRGINIA

Technical Report

SECTION A. POTENTIAL DREDGING TECHNOLOGY ON WORLD MARKET

SECTION B. ENVIRONMENTAL ASSESSMENT OF ENGINEERING ALTERNATIVES FOR CAPTURING, STABILIZING, OR REMOVING KEPONE FROM BAILEY BAY, BAILEY CREEK, AND GRAVELLY RUN, CITY OF HOPEWELL AND PRINCE GEORGE COUNTY, VIRGINIA.

SECTION C. COST ESTIMATES

SECTION D. SURVEYS

SECTION E. SUBSURFACE INVESTIGATIONS

APPENDIX 1

PREPARED BY THE
NORFOLK DISTRICT, CORPS OF ENGINEERS
DEPARTMENT OF THE ARMY

SECTION A

POTENTIAL DREDGING TECHNOLOGY ON WORLD MARKET

SECTION A

POTENTIAL DREDGING TECHNOLOGY ON WORLD MARKET

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AUTHORIZATION

GENERAL

On 2 May 1977, the Norfolk District Engineer submitted a "Summary of Alternatives for Capturing, Stabilizing, or Removing Kepone from Bailey Bay, Bailey Creek, and Gravelly Run" near Hopewell, Virginia to the U.S. Environmental Protection Agency (EPA). The James River navigation channel was not included.

On 13 May 1977, EPA accepted the proposed alternatives and authorized initiation of preliminary studies thereon. In this connection EPA stated that:

> "1. . . . Only those methods to control sediment, turbidity, or erosion of contaminated soils are considered to be within the scope of the Corps of Engineers study effort.
>
> 2. All alternatives employing dredging will evaluate all potential dredging technology on the world market as well as methods to reduce and control resuspension and concomitant secondary pollution . . . ."

Of the 18 alternatives under consideration, 7 included dredging. They are as follows:

Table A-1. SUMMARY OF DREDGING ALTERNATIVES

Alternative Number	Location	Alternative
5	Gravelly Run	Dredge new channel adjacent to existing channel; seal side slopes of new channel to prevent seepage, if necessary; and cover contaminated area.
6	Gravelly Run	Dredge all contaminated material in Gravelly Run and pump into predetermined disposal area. This would require a treatment facility at the disposal area to treat all effluent.
10	Bailey Creek	Dredge new channel adjacent to existing channel; seal side slopes of new channel to prevent seepage, if necessary; and cover contaminated area.
11	Bailey Creek	Dredge all contaminated material in Bailey Creek and pump into predetermined disposal area. This would require a treatment facility at the disposal area to treat all effluent.
13	Bailey Bay	Dredge all contaminated material in Bailey Bay and pump into predetermined disposal area. This would require a treatment facility at the disposal area to treat all effluent.

Table A-1. SUMMARY OF DREDGING ALTERNATIVES
(CONT'D)

Alternative Number	Location	Alternative
15	Bailey Bay) Bailey Creek) Gravelly Run)	Construct a dam at the mouth of Bailey Creek, dredge Bailey Bay, and use Bailey Creek as a disposal area. Also, construct a dam at the mouth of Gravelly Run and divert the discharge into Bailey Creek. In addition, a treatment facility would be constructed at the mouth of Bailey Creek to treat all effluent from the disposal area.
17	Bailey Bay) Bailey Creek) Gravelly Run)	Construct a levee from Jordan Point to the east side of Bailey Creek and use the confined area as a disposal area for dredging the remainder of Bailey Bay and all contaminated areas in Bailey Creek and Gravelly Run. Treat the effluent from the disposal area until the dredging of each area is complete. The disposal area would then be sealed with an impervious blanket, covered with topsoil, and planted.

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"Mechanical Dredges" by Adolph W. Mohr, ibid.

"Dredging Environmental Effects and Technology" by Eisuke Sato, Proceedings of World Dredging Conference (WODCON VII), 1976.

"The Management of Bottom Sediments of the Port Tagonoura," by Masao Sato, Mgr Planning and Inspection Section, Civil Engineering Division, Shizuoka Prefecture Japan.

"Turbidity Caused by Dredging" by Tokuji Yagi, Taisei Koiwa, and Shyoji Miyazaki, Proceedings of WODCON VII, 1976.

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"Oozer Pump dredge, TAIAN MARU," by Toyo Construction Company.

"Management Techniques of Bottom Sediments Containing Toxic Substances," by Hiromi Koba, Kunihide Shinohara, and Eisuke Sato, Japan, Dredging and Reclamation Engineering Association.

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"Techniques for Reducing Turbidity Associated with Present Dredging Procedures and Operations," WES Contract Report D-76-4.

"Dredging: Environmental Effects and Technology," Proceedings of WODCON VII, 1976.

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"Proceedings of the Speciality Conference on Dredging and its Environmental Effects," January 26-28, 1976, published by the American Society of Civil Engineers.

"World Dredging and Marine Construction," (magazine issues).

"Predicting and Controlling Turbidity Around Dredging and Disposal Operations," by Dr. William D. Barnard, "Proceedings of the Special Conference on Dredging and its Environmental Effects," January 26-28, 1976, published by American Society of Civil Engineers.

"Silt Curtains for Dredging Turbidity Control," by Edward E. Johanson, ibid.

Data on TST and DCM Systems by Takenaka Komuten Co., Ltd.

"Delta Model 212" by Delta Dredge Corporation.

Data on the Waterless Dredge by Waterless Dredging Company.

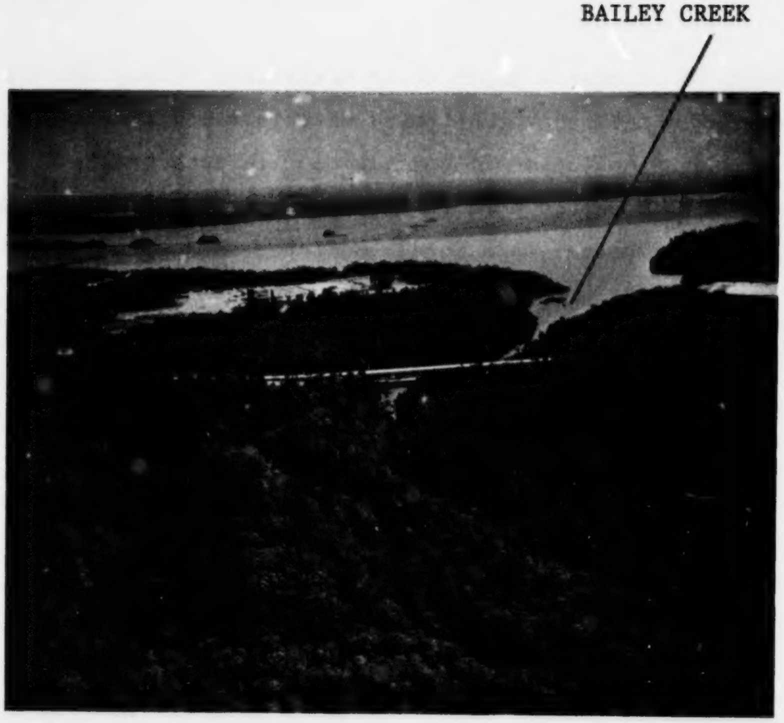
SCOPE

This report concentrates on dredging activities throughout the world, particularly in the removal of toxic materials and the attempts made to reduce secondary pollution in connection with such dredging. Any detailed analysis should concurrently consider dredging, conveyance, treatment, and disposal as a total and integrated system and not as separate components.

DESCRIPTION OF AREAS UNDER INVESTIGATION

BAILEY BAY

Bailey Bay, as shown on plate 1, is a low-lying area located adjacent to the James River at Hopewell, Virginia. It is about 2.4 miles long, averages 1/2 mile in width, and encompasses about 800 acres. The range of tide is normally about 2.6 feet. At mean high tide, the bay is covered with about 3.6 feet of water. However, the major portion of the bay is covered with 1 foot of water or less at low tide. Thus, if Kepone is located only close to the surface, any dredging equipment considered would have to have a draft of only about 2 or 3 feet and be capable of dredging shallow water sediments at depths of 0 to 3 feet, so as not to dredge excessively below the surface. The logs of the borings taken indicate fine organic clay mixed with some fine sand down to a depth of about 8 feet. The following are photographs of the bay.


BAILEY CREEK

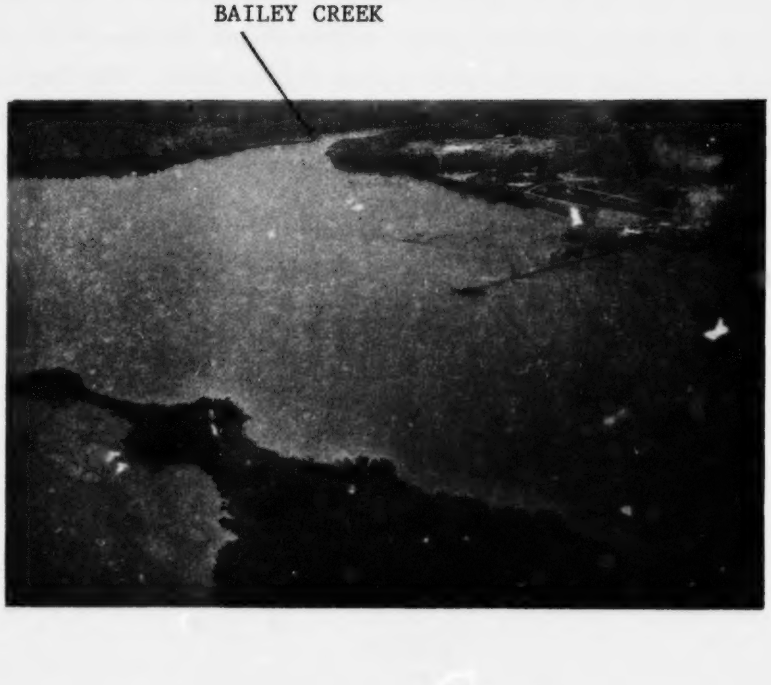

BAILEY CREEK

Figure A-1. Bailey Bay

BAILEY CREEK

Bailey Creek, as shown on plate 1, is about 3.2 miles long to the bridge crossing on Virginia Route 156. Cross sections indicate the following:

Table A-2. TOPOGRAPHICAL DATA FOR BAILEY CREEK

Cross section	Distance in feet above mouth of Bailey Creek	Elevation of river bottoms above msl	Elevation of river bottoms above mlw	Width of cross section, in feet, at following elevations above mean sea level 0	+2	+5	Remarks
BC-1	100	-4.0	-3.5	710	1,090	2,190	A major portion of the area is covered with marsh and woods
BC-2	2,500	-2.2	-1.7	170	580	900	Virginia Route 10 crossing
BC-3	6,000	-2.2	-1.7	80	560	600	Swamp and woods
BC-4	8,900	-0.2	0.3	0	1,020	1,260	Swamp, marsh, and woods
BC-5	13,850	0.8	1.3	0	70	610	Marsh; includes a utility pole
BC-6	17,100	4.0	4.5	0	0	24	Virginia Route 156 crossing

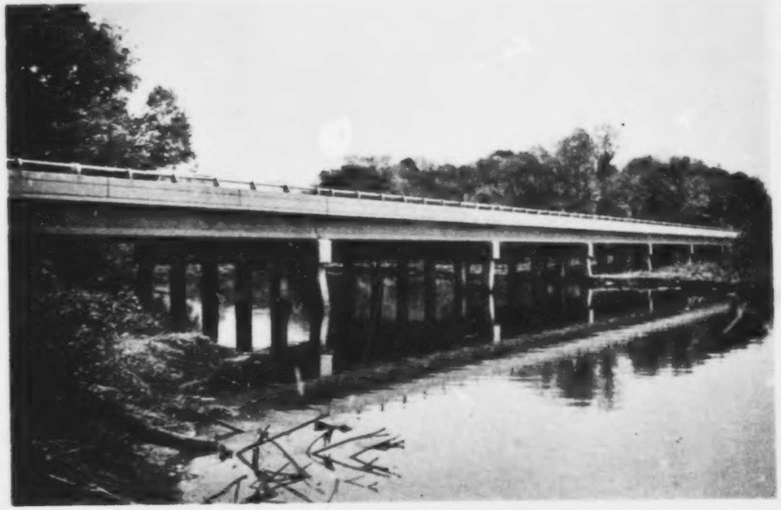
Note: Mean sea level = 0.5 foot above mean low water.

Bailey Creek has a drainage area of 14 square miles above the bridge crossing on Virginia Route 156 and 20 square miles at the mouth. Thus, there would normally be at least 3 to 4 cubic feet per second of runoff in the creek during the hot summer months. Plate 2 indicates that the tide extends for a considerable distance up Bailey Creek; therefore, a small dredge might enter the creek although it would have difficulty traversing Virginia Route 10 crossing. Its low clearance could present problems unless the dredge could be removed from below the bridges to above the structures. It is questionable whether the machine could dredge hundreds of feet into the swamp with trees and their roots located along both sides of the creek, as shown on table 2. It would undoubtedly be necessary to remove trees from the area before dredging can be accomplished. Possibly some type of circular saw (swamp chipper) could be installed in front of a dredge, such as a cutterhead, to reduce the roots to a small size. Dredging around Virginia Routes 10 and 156 and existing utility poles would have to be carefully done to insure that the foundations of these structures remain intact.

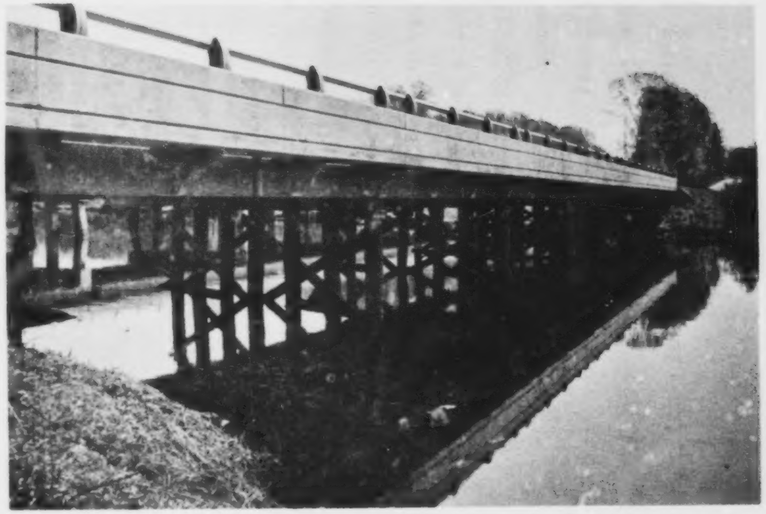
Drill holes indicate that the material in the creek bottom includes fine to medium sand and organic silts and clays that are quite plastic. Photographs of Bailey Creek follow.

Mouth of Stream

Looking downstream from Virginia Route 10

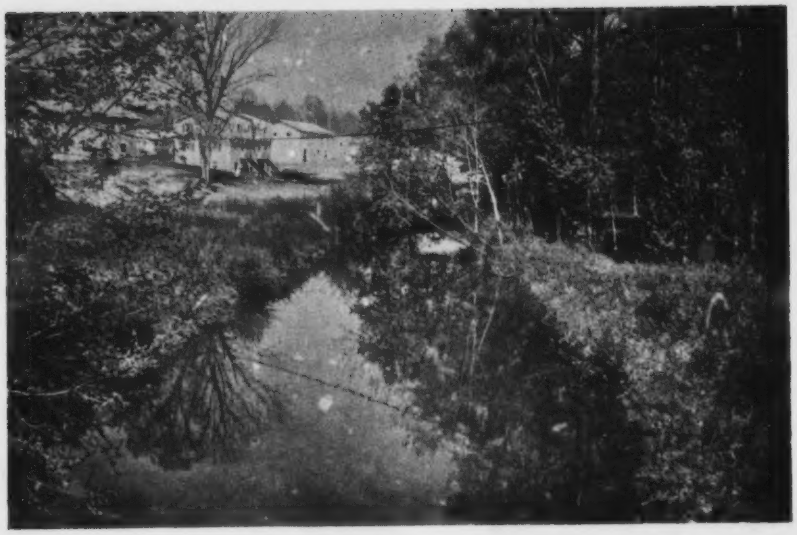


Downstream bridge on Virginia Route 10

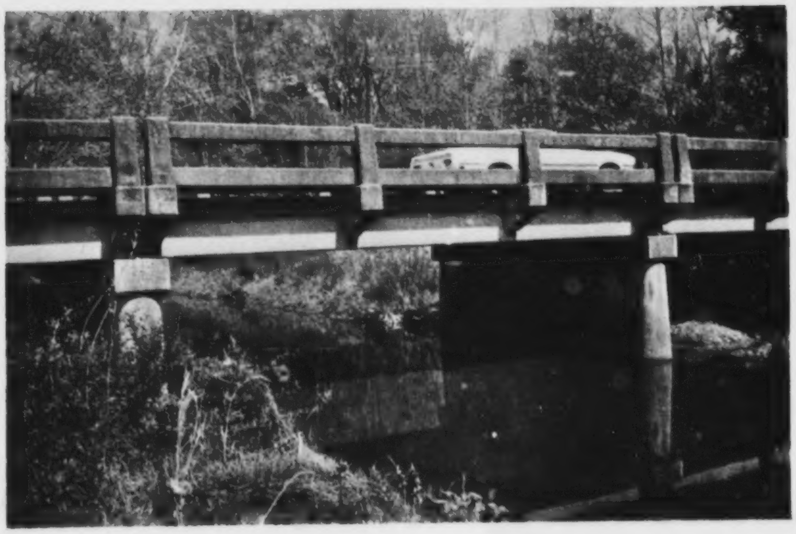


Upstream bridge on Virginia Route 10

Figure A-2. Bailey Creek



Looking downstream from Route 156



Virginia Route 156

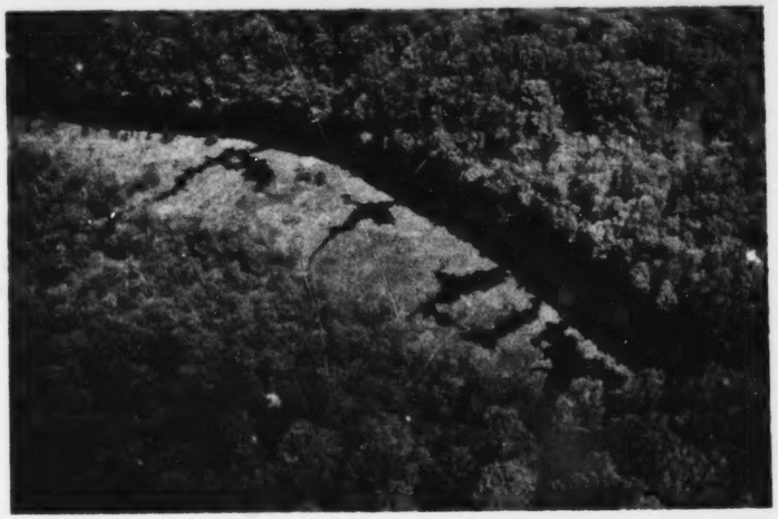
Figure A-3. Bailey Creek

186<

Mouth of Bailey Creek at low tide

Route 10 bridges near mouth

Wooded section south of bridges



Wetland area approximately 2000 feet above mouth

Figure A-4. Bailey Creek

GRAVELLY RUN

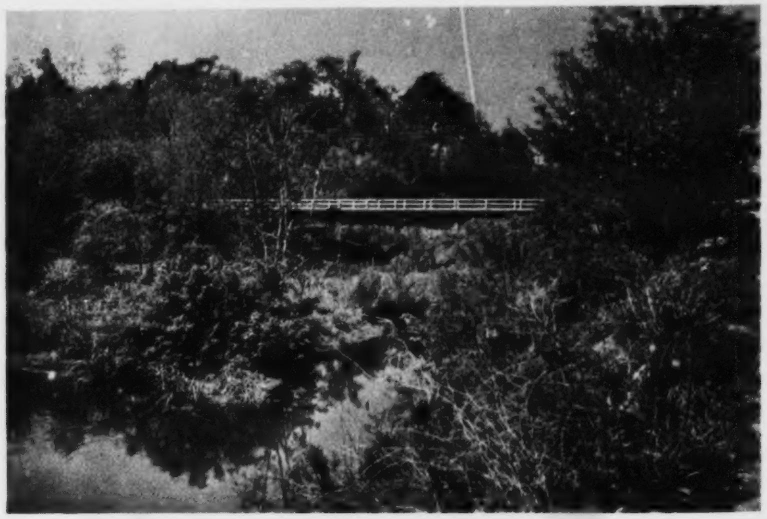
Gravelly Run, as shown on plate 1, is about 1.4 miles long to the bridge crossing on Virginia Route 10. The following table presents data based on the available cross sections. Photographs of the creek follow.

Table A-3. TOPOGRAPHICAL DATA FOR GRAVELLY RUN

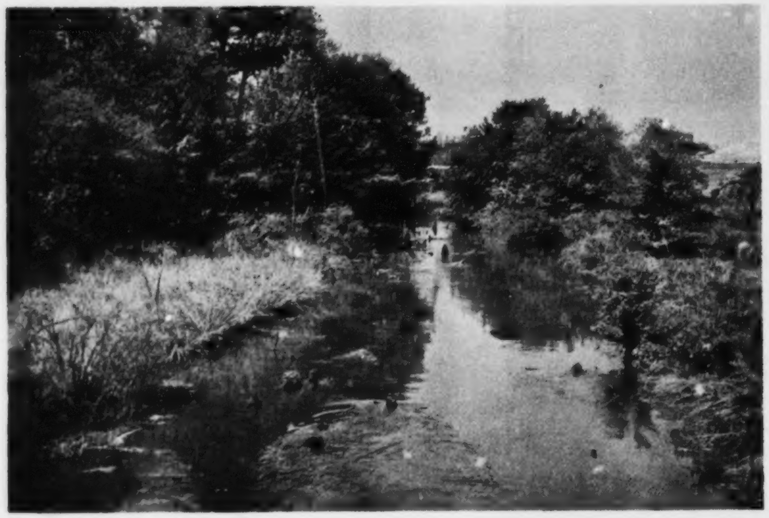
Cross section	Distance in feet above mouth of Gravelly Run	Elevation of river bottoms		Width of cross section, in feet at following elevations above mean sea level				Remarks
		above msl	above mlw	0	+2	+5	+10	
GR-1	0	-5.0	-4.5	50	60	90	640	Woods, pond, brush
GR-2	2,150	-0.5	0	10	50	60	90	Private bridge
GR-2A	3,370	2.5	3.0	0	0	50	280	Pipeline crossing
GR-3	4,050	3.4	3.9	0	0	20	260	Woods and rubble
GR-3A	4,920	4.9	5.4	0	0	0	150	Pipeline crossing
GR-3B	5,180	4.9	5.4	0	0	0	150	Pipeline crossing
GR-4	6,120	11.9	12.4	0	0	0	0	Roadway crossing with culverts
GR-5	7,150	19.5	20.0	0	0	0	0	Roadway crossing with culverts
GR-6	7,500	20.0	25.0	0	0	0	0	Virginia Route 10 crossing

Note: Mean sea level = 0.5 foot above mean low water.

Looking downstream from Continental Can bridge

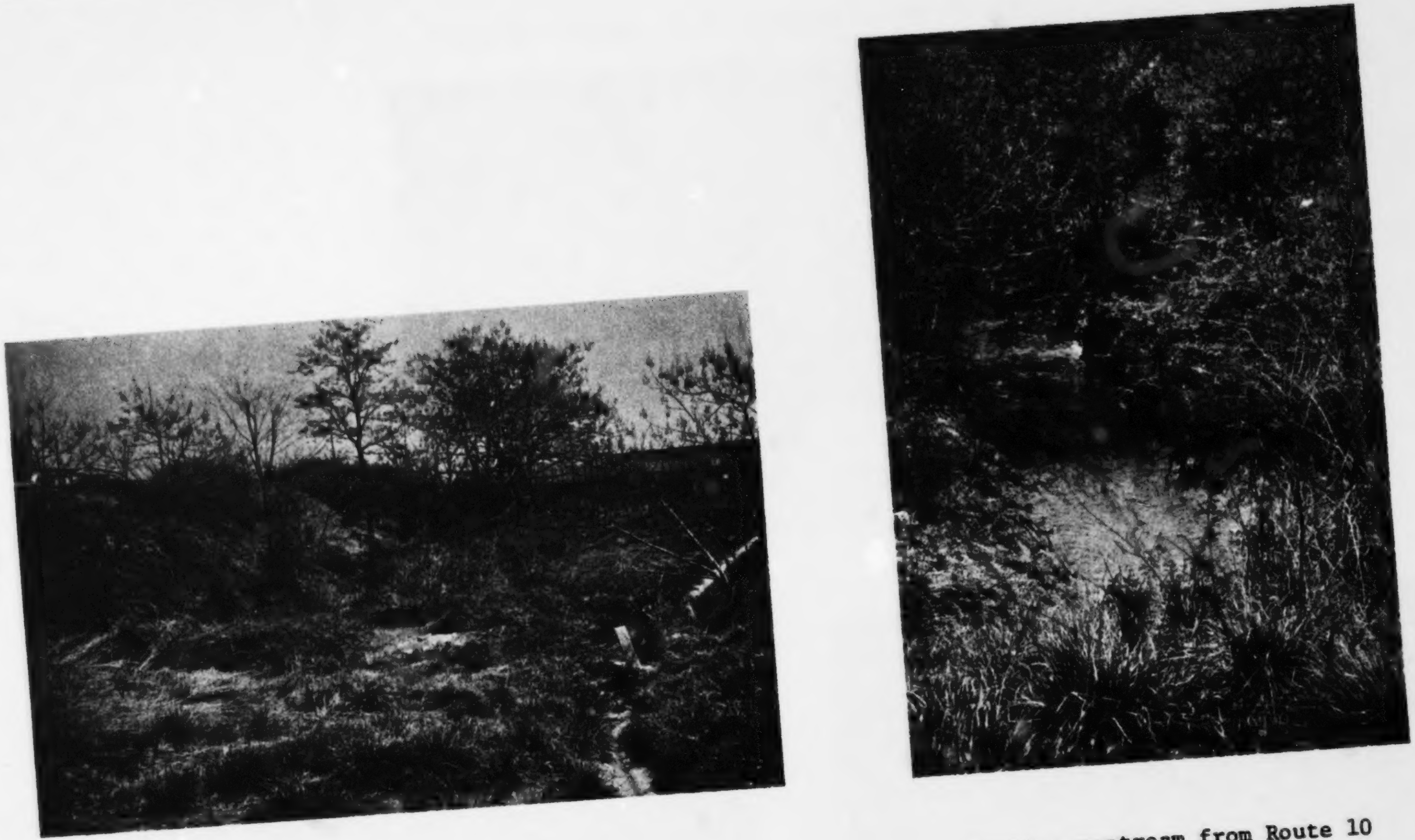


Continental Can Bridge



Looking upstream from Continental Can bridge

Figure A-5. Gravelly Run



Looking downstream from Route 10

Looking upstream from Route 10

Figure A-6. Gravelly Run

The previous table indicates that there is very little of the stream--possibly upstream only to the vicinity of cross section number 2--that is available for the flotation of dredging equipment in Gravelly Run. Furthermore, a dredge would have difficulty in navigating the creek due to the number of roadway and pipeline crossings. The foundations of all bridge crossings would have to be preserved.

REQUIRED EXCAVATION

The following table provides an indication of the magnitude of the excavation problem. It shows the considerable excavation involved within two of the areas under consideration.

Table A-4. QUANTIITES TO BE DREDGED (CUBIC YARDS)

Location	From	To	Length, miles	Estimated excavation 1/ assuming it necessary to dredge to a uniform depth of 2 feet	4 feet	6 feet
Bailey Bay	Jordan Point	Allied Dock	2.4	3,392,000	6,785,000	10,177,000
Bailey Creek	Mouth	Virginia Route 156	3.2	1,509,000	2,657,000	3,791,000
Gravelly Run	Mouth	Virginia Route 10	1.4	60,000	102,000	144,000

1/ Quantities shown are based on dredging 2,4, and 6 feet below the existing ground level up to a point where the ground rises to elevation 5 m.s.l.

DREDGING TECHNOLOGY IN THE UNITED STATES

GENERAL

A dredge can be defined as a machine that is equipped with scooping and/or suction devices that are capable of removing mud, sand, silt, and similar material from the bottom or sides of a waterway. It has been used to deepen harbors and rivers and create canals. Lately, dredges have been designed in some countries to remove noxious and/or toxic substances from waterways.

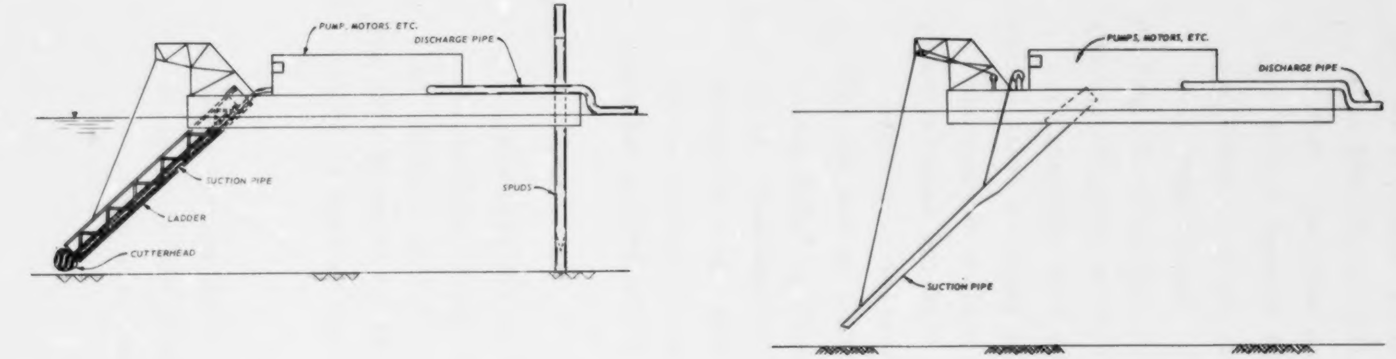
Dredges in use today can be generally divided into three categories--mechanical, hydraulic, and pneumatic. Mechanical dredges normally lift the dredged material above the waterline by means of buckets or scoops of various designs and deposit it in a barge or similar conveyance for transport and disposal. Hydraulic dredges generally move bottom material via a centrifugal pump and pipeline directly toward a disposal area. Pneumatic dredges move bottom material by compressed air. Mechanical dredges can remove bottom material at near inplace density, whereas hydraulic and pneumatic dredges have to add dilution water to form the dredged material slurry. A hydraulic dredge can add as much as 3 parts or more of diluting water to one part of the material dredged. A pneumatic dredge requires somewhat less water. This increase in volume of slurry, due to the addition of dilution water, adds to the problems associated with the deposition of dredged material. Confined disposal areas must be large enough to contain the increased volume. This is especially important when handling fine-grained materials that do not settle out. Thus, when the dilution water is drained off from confined disposal areas, the water may still contain large quantities of fine particles and pollutants.

HYDRAULIC DREDGES

The following types of hydraulic dredges are in general use:

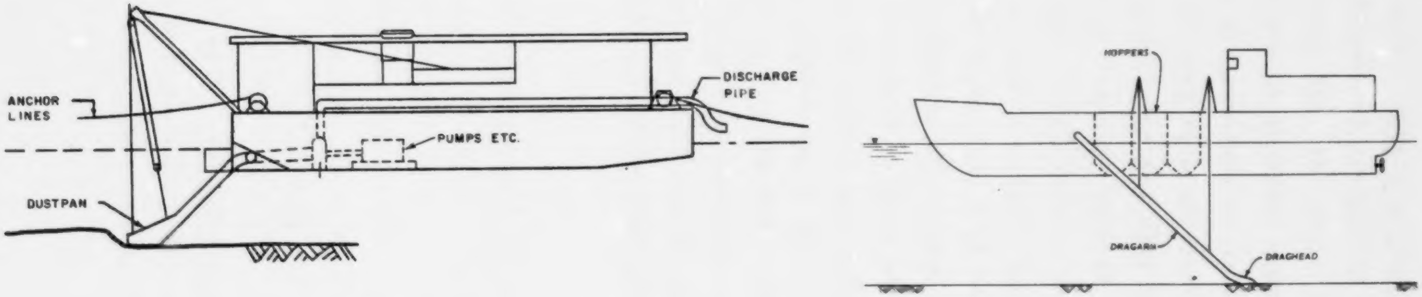
- Cutterhead pipeline dredge
- Plain suction pipeline dredge
- Dustpan hydraulic dredge
- Hopper dredge
- Sidecasting dredge

Sketches of some of these are shown on the following page.


PUMP, MOTORS, ETC.
DISCHARGE PIPE
SUCTION PIPE
LADDER
CUTTERHEAD
SPUDS
PUMPS, MOTORS, ETC.
DISCHARGE PIPE
SUCTION PIPE

Cutterhead Pipeline Suction Dredge

Plain Suction Pipeline Dredge


ANCHOR LINES
DUSTPAN
DISCHARGE PIPE
PUMPS ETC.
HOPPERS
DRAGARM
DRAGHEAD

Dustpan Dredge

Trailer Hopper Dredge

Figure A-7. Hydraulic Dredges

Cutterhead Pipeline Dredge. This dredge is a highly developed machine that is used throughout the world. A rotary cutter on the end of a dredge ladder bites into and scarifies the bottom material. Then a centrifugal pump sucks water and the cut material through a pipeline, possibly floated on pontoons, to a disposal site, which is sometimes located far from the area that is being dredged. Some dredges have been equipped with gas ejection systems to insure that gases trapped in fine-grained dredged material do not enter the suction pump and thereby create pumping difficulties. The diameter of the pump discharge in pipeline dredges varies from 6 to 42 inches. The required draft varies from as little as 2 feet to 12 or 15 feet. The smaller dredges are sensitive to waves. The production rate varies with the material being dredged and the pumping distance. Some of the smaller cutterhead pipeline dredges can dredge 100 cubic yards per hour in mud and soft clays, whereas the large dredges can dredge as much as 2,000 cubic yards per hour. The dredge is generally not self-propelled. It is controlled on stern-mounted spuds and is swung from one side of the channel to the other by anchored swing wires. By the nature of the cutter, considerable agitation and disturbance of the bottom sediments may occur.

Plain Suction Pipeline Dredge. This is similar to the previously described dredge, excluding a cutterhead. This type of machine is usually used in free-flowing material where agitation by a cutter is not necessary. With light sedimentation, material is drawn up with the water. With some soils, one or more water jets may be used to loosen and fluidize the material.

Dustpan Hydraulic Dredge. This is a variation of the suction pipeline dredge and is especially adapted to remove sandbars and alluvial deposits such as sand, silt, mud, and loose gravel from the navigation channels of the Mississippi, Missouri, and Ohio Rivers. Its wide suction inlet is similar in configuration to a vacuum cleaner. Powerful, high-pressure water jets located along the length of the dustpan head are used to fluidize the material on the bottom of the river. It is then picked up by the wide but shallow suction opening, pumped through the discharge line, and then returned into the water adjacent to the channel. Here it can be moved downstream, together with other sediments, by velocity of the water near the river bottom. While the practice of jetting improves efficiency, this action produces considerable resuspension of material near the river bottom.

Hopper Hydraulic Dredge. This dredge is equipped with hoppers or bins that store the hydraulically dredged material until it is carried to a designated disposal area. It is equipped with large centrifugal pumps similar to those employed by suction dredges. The suction pipes (drag arms) are hinged on each side of the ship with the intake or drag head toward the stern of the vessel. The head is dragged along the bed of the area to be dredged as the vessel moves forward. The dredged material is lifted up the suction pipe and stored in the hoppers of the ship. The hopper dredge is highly mobile and, unlike the pipeline dredges previously described, has no "fixed" pipeline for transporting dredged material to a disposal area. Dredging is at times continued to the point where the hoppers start to overflow and the excess water containing fine materials is allowed to flow back into the water body. Depending on the hopper dredge, disposal can take place in open water by opening the bottom of the hoppers or the dredge can tie up to a pier and pump dredged material directly ashore into an upland disposal area. These dredges range in size from a hopper capacity of 300 cubic yards to as much as 11,700 cubic yards and require a minimum depth of 15 feet.

Sidecasting Dredge. This dredge is a relatively new development and one particularly effective where the littoral currents do not retain a significant amount of dredged material in the navigation channel. The material is picked up with dilution water by the draghead sliding over the bottom. It flows through suction piping and a centrifugal pump before being pumped back into the waterway, many feet clear of the dredged channel, through pipes ranging from 70 to 170 feet in length depending on the dredge involved.

MISCELLANEOUS HYDRAULIC DREDGES

Ellicott Machine Corporation has recently developed an underwater bucket wheel excavator which operates like the cutterhead pipeline dredge. However, a wheel with buckets attached thereto is substituted for the rotary cutterhead. As the wheel turns, the buckets scoop up the material and deposit it into a receiving hopper where it proceeds into the suction pipe. The manufacturer states that the wheel, with its attached buckets, has ecological advantages over the conventional "egg beater" style cutterhead dredge which overdigs and mixes strata of polluted material with nonpolluted material. He stated that since the bucket wheel sweeps the bottom with a positive acquistion characteristic, it is more effective in skimming the bottom to the required depth to remove the polluted stratum without mixing it with other material. It is understood that up to this time, it has been used mainly in mining highly consolidated sediment.

Marcona Corporation has developed a hydraulic device for the slurry handling of materials. It consists of a portable cylindrical capsule from 4 to 7 feet in diameter, from 7 to 16 feet in height, and weighing as much as 8 tons. The capsule contains jets that are supplied with a stream of water at high pressure. It is crane operated and is rotated at about one revolution per minute. As the device rotates, the high pressure stream of water emanating from the jets transforms the dry compacted material to be removed over a full 360 degrees into a slurry. The high water pressure of the jets can slurry material up to

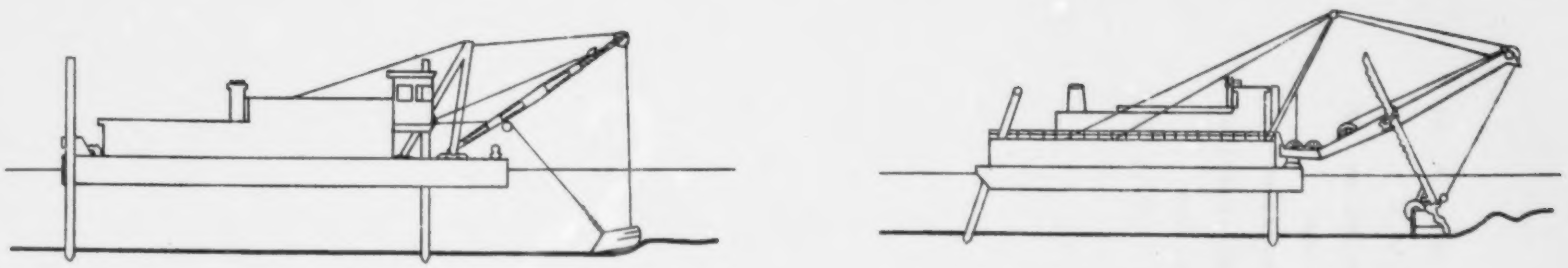
60 feet in radius from the capsule. A vertical centrifugal pump in the cylinder discharges the slurry into a pipeline for movement to a disposal area. The capsule also contains hydraulic drive motors and an eductor jet pump to maintain suction and enable total discharge. Makeup water is supplied by an electric motor-driven, high-pressure water pump. Regulation of the water supply and water pressure enables control, within certain limits, of solids density and slurry flow. This hydraulic device has been used primarily in mining and mineral processing industries.

MECHANICAL DREDGES

The following types of mechanical dredges are now in use:

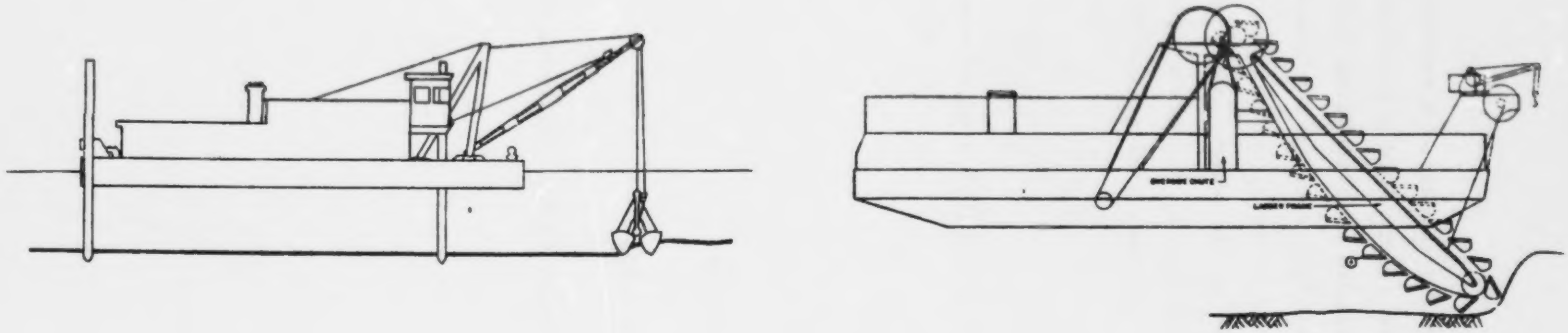
- Dragline dredge
- Dipper dredge
- Grab bucket dredge
- Endless chain dredge

Sketches thereof are shown on the following page.



Dragline Dredge

Dipper Dredge



Grab Bucket Dredge

Endless Chain (Bucket Ladder) Dredge

Figure A-8. Mechanical Dredges

Dragline Dredge. This dredge is an ordinary metal scoop suspended from a swinging boom on a crane that is mounted either on a barge or truck. The scoop is lowered into the material to be excavated and is then placed in such a position as to slice the earth away as the scoop is drawn towards the crane. When the scoop is filled, it is lifted and the dredged material is deposited either in a barge or on the bank. Considerable turbidity is created during the operation.

Dipper Dredge. This dredge includes a single boom-mounted shovel generally located on a floating dredge, caterpillar, or crawling tractor. The shovel is forced into the material to be dredged and the material is scooped up. The shovel is then lifted and the dredged material is deposited either in a barge, truck, or other conveyance or on the bank. The powerful action of this equipment causes considerable sediment disturbance during digging and a significant loss of fine material from the bucket may occur during the hoisting process.

Grab Bucket Dredge. This dredge consists of a "grab" bucket suspended from a swinging boom or crane. It is often called a clamshell dredge when there are two halves to the bucket. Material is removed by forcing the opposing bucket edges into it while the dredge or truck on which it is mounted is stationary. The bucket is then closed and lifted; the dredged material is then deposited either in a barge or other conveyance or on the bank.

These dredges usually excavate a full bucket of material, but during hoisting, drag forces wash away part of the load. Once the bucket clears the water surface, additional losses occur through rapid outflow of entrapped water through the jaws and slumping of the material heaped around the rim. Even under ideal conditions, substantial losses of loose and fine sediment usually occur.

Endless Chain (Bucket Ladder) Dredge. This dredge consists of a continuous or endless chain of buckets pulled around a dredging ladder. Material is removed by forcing the single cutting edge of successive buckets into the material. The dredge lifts the buckets and deposits the dredged material in a barge, conveyor belt, or other conveyance. As with the dipper dredge, considerable sediment disturbance and loss of fine material back to the water column are inherent in this method. This type of dredge is not used actively in this country. European dredge experts have stated that if buckets are not overfilled, the material loss on their way into the ladder could be minimal.

METHODS TO REDUCE RESUSPENSION

Mud Cat Dredge. This dredge consists of a hull 8 feet wide by 30 feet long with the ability to operate in about 27 inches of water. It has a 175-horsepower diesel engine that drives a centrifugal pump. There is a slow speed, 8-foot wide, auger-type, horizontal cutterhead attached to a hydraulic boom at the front end of the machine. The knives dislodge and cut up the material, and the auger moves the material laterally toward the suction pipe. After passing through the centrifugal pump, the slurry (silt and water) is transported through an 8-inch discharge pipe to a disposal area. A mud shield surrounds the auger and helps channel the material toward the pump suction intake. Teeth along the forward edge of the mud shield provide additional cutting capability when material protrudes above the water. The mud shield is retractable over the auger and thereby minimizes mixing of the disturbed bottom sediments with the surrounding water. Photographs of the Mud Cat dredge follow.

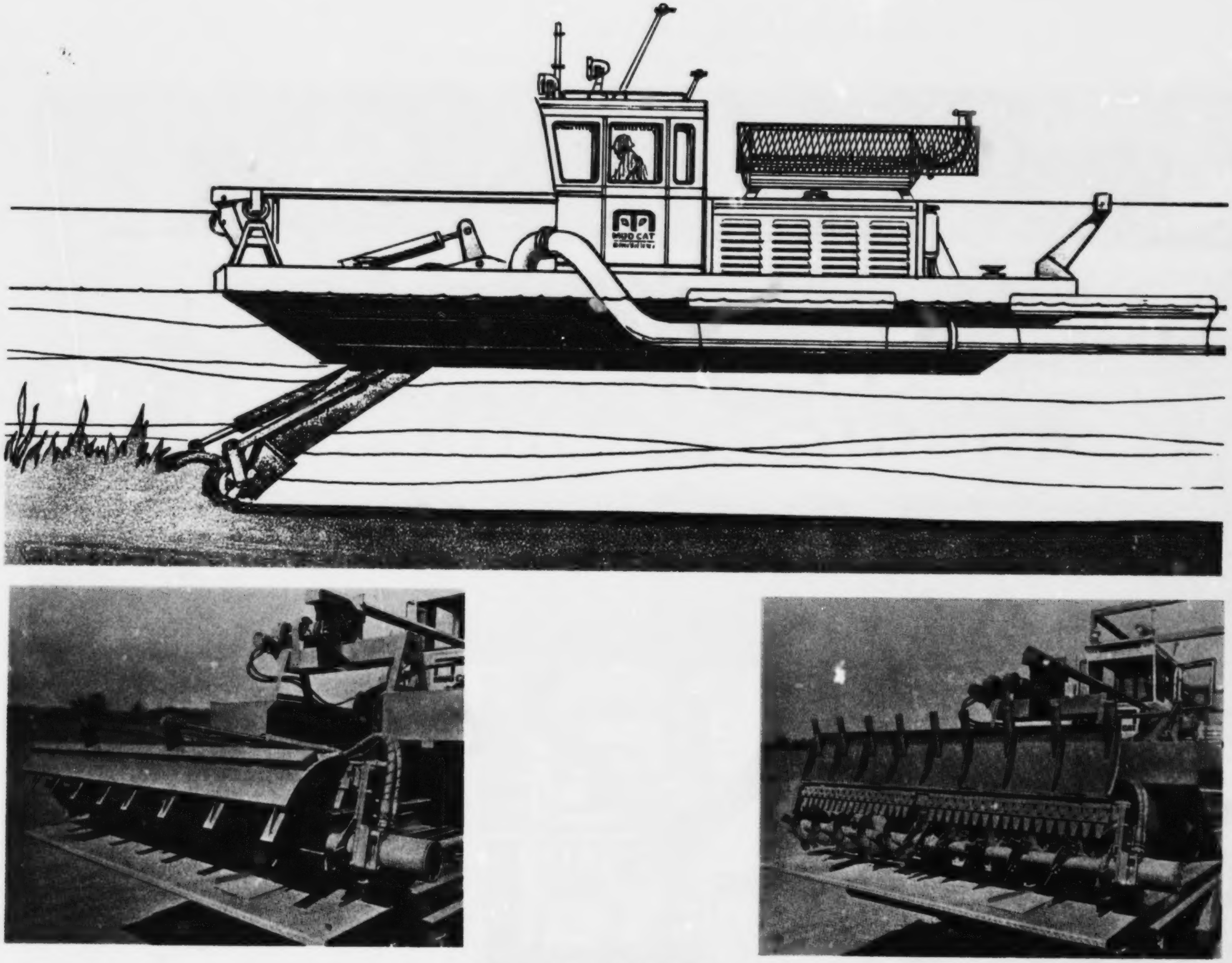


Figure A-9. Mud Cat Dredge
(National Car Rental Systems)

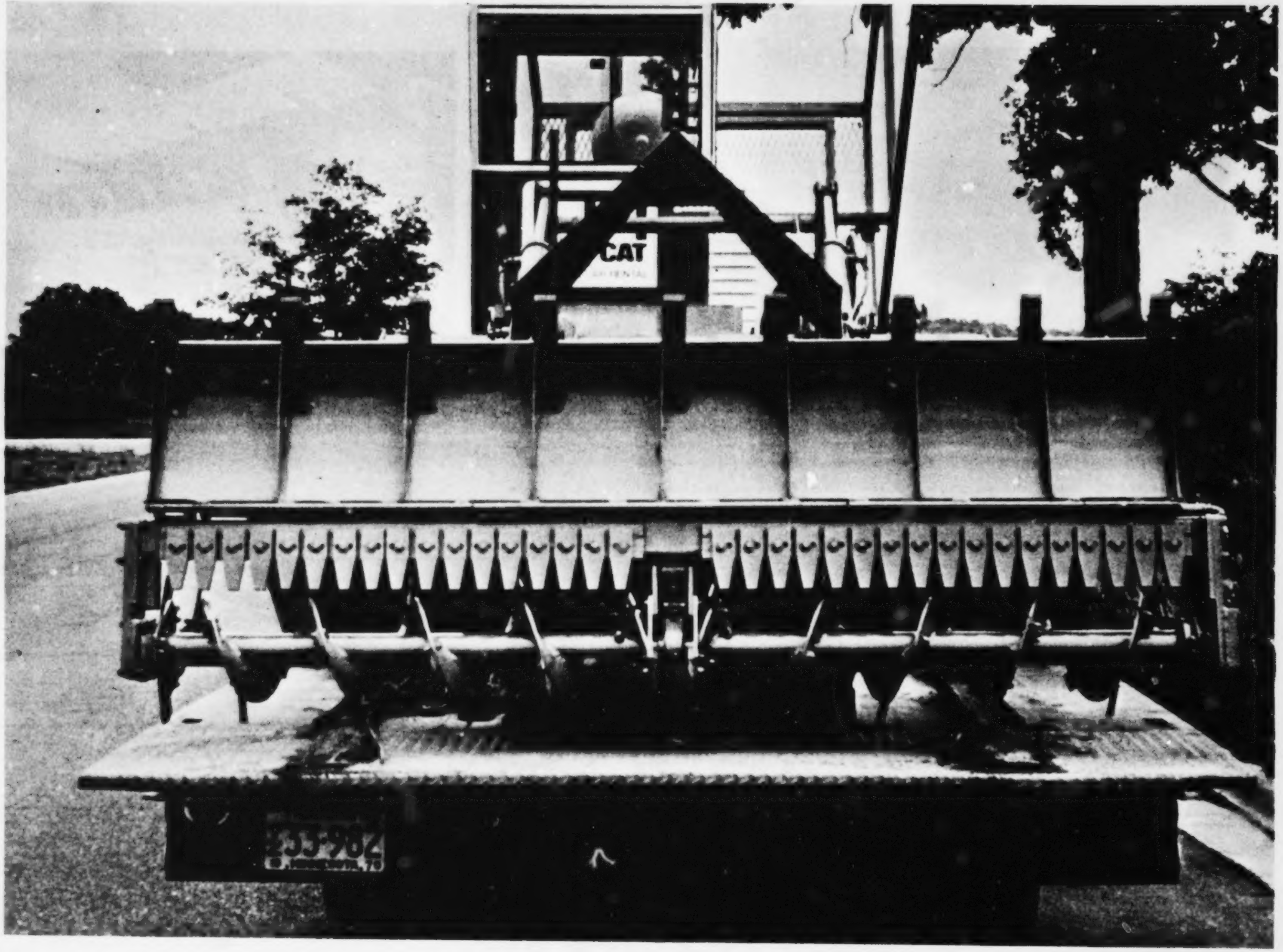


Figure A-10. Mud Cat Dredge
(National Car Rental Systems)

The Mud Cat weighs about 10 tons and can usually be transported over the highway. During dredging operations, it is propelled along a taut, fixed cable. The dredge is not self-propelled. Therefore, after each 8-foot wide pass has been made, the barge has to be winched over another 8 feet by pullover cables and the pipeline length adjusted until the project is completed.

According to a report prepared for the Waterways Experiment Station (WES), May 1976, Contract Report D-76-4, the Mud Cat is useful in shallow harbors and basins where fine-grained sediments have to be dredged and turbidity is a problem. According to another report prepared for WES, Technical Report H-72-8, November 1972, the Mud Cat is a small dredge optimized for removing mud, silt, and aquatic plants with a minimum of turbidity. However, hard bottoms, rough weather, some types of precision work, and other circumstances could not be handled by such equipment. It can discharge approximately 1,500 gallons per minute of slurry with a solids concentration of 10 to 30 percent. This varies from 45 to 135 cubic yards of solids per hour.

A report prepared for the Environmental Protection Agency in 1973 states that the Mud Cat dredge has proved to be very efficient in removing the deposited sediments from a pond bottom and preventing the resuspension of the sediments during the dredging operations. Minor perturbations to the smooth dredging operation were the result of:

a. Clogging of the pump or auger by large debris and objects such as tree stumps, logs, large rocks, or lengths of barbed wire. No damage was done to the dredge due to this blockage and dredging was continued as soon as the pump and auger were shut down and the debris removed.

b. Bars of sediment which protrude above the water level. Dredging operations were slowed by cuts which had to be made above water level. In this case, the auger and intake were raised and the sediment dragged back into the pond by the mud shield. This operation was repeated until adequate draft (approximately 18 inches) was available for passage of the Mud Cat. Naturally, this operation took longer than a normal dredging operation, but was well within the capabilities of the Mud Cat.

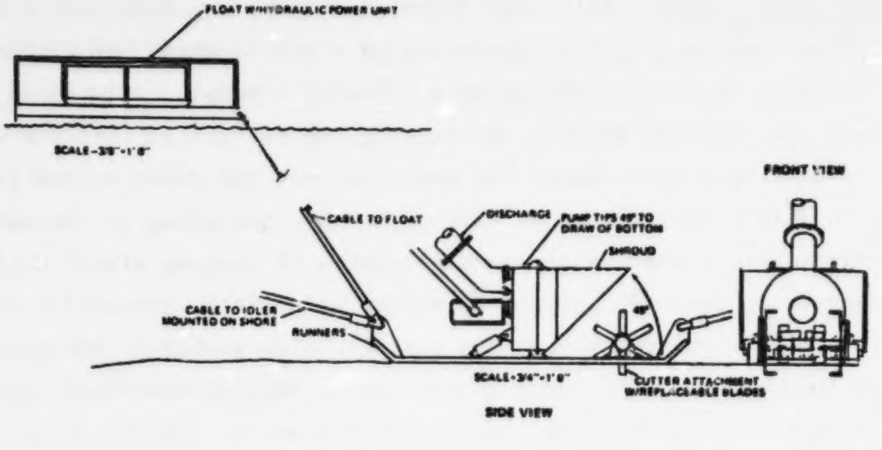
c. The need for quite a number of positioning moves of the dredge in order to properly level the banks of the pond. Since movement of the Mud Cat is limited to a straight line along a taut, fixed cable, this cable had to be moved a greater number of times per cubic yard of sediment dredged when short cuts were being made in order to properly level the pond banks.

Delta Dredge. The Delta Dredge Corporation Model 212 was developed 2 years ago. It is a lightweight piece of dredging equipment featuring a double cutterhead in a submerged 12-inch discharge pump that can operate 2,000 feet without a booster. It can dredge up to 100 cubic yards of sand per hour and more of silt or soft material. The hull contains 4 pontoons and the operating draft is 32 inches. The two counter rotating reversible cutters provide a relatively shallow 7-1/2 foot-wide-cutting swath. They operate at low speed and it is understood that the turbidity levels are low. The dredge is 16 feet wide and 40 feet long and its weight is 15 tons. It is portable for ease of transport and maneuverable in small bodies of water. The unit can be used to clean out silted lakes, industrial settling ponds, and sewage lagoons. According to the company, the equipment dredges a high percentage of solids. One dredge was used to clean out a 6-inch to 4-foot thick layer of contaminants pumping 10,000 cubic yards with a 2-man crew. The largest job was the removal of about 30,000 cubic yards from a reservoir that had silted. In this case, pollution was not involved. The following is a figure of this dredge.

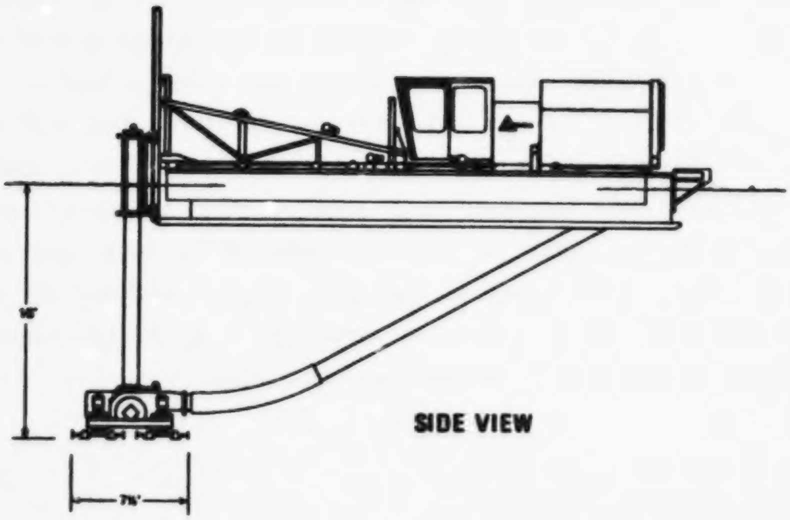
Waterless Dredge. Waterless Dredging Company has developed a dredging system wherein a cutter, operating as a paddle wheel and a pump (referred to by the company as a Crisafulli pump), is inclosed within a half cyclindrical shroud. By forcing the cutterhead into the material, the cutting blades remove the material near the front of the cutterhead with little entrainment of carrier water. According to the manufacturer, this system is apparently capable of pumping slurry with a solid content of 30 to 50 percent by weight with little generation of turbidity. The company states that its high viscosity dredging equipment cleaned a 7-acre sludge lagoon pumping one-fourth the liquids. On another job, the dredge removed by pumping about 1,000,000 gallons of material from a wastewater clarifier. The material in the clarifier was so thick that it virtually would not flow. The following is a figure of this dredge.

TECHNIQUES FOR REDUCING TURBIDITY ASSOCIATED WITH PRESENT DREDGING OPERATIONS

In 1976 John Huston, Inc., under contract to the United States Army Engineer Waterways Experiment Station conducted a study of dredged-induced turbidity. One of the primary goals was to evaluate operational techniques that may be used with existing technology and equipment to reduce turbidity created by the dredging plant. Evaluation of dredge-induced turbidity was based primarily on the experience of the authors and other people associated with the dredging industry. In this connection it is interesting to note that the report states that there have been some attempts made to contain material not picked up by the cutter by adding shields or hoods around or over the cutter. In the few reported instances where these devices were tried, very little turbidity reduction resulted. Some of the recommendations included in the report include the following:


FLOAT W/HYDRAULIC POWER UNIT
SCALE - 3/8" = 1' 0"
FRONT VIEW
CABLE TO FLOAT
DISCHARGE
PUMP TIPS 45° TO DRAW OF BOTTOM
SHROUD
CABLE TO IDLER MOUNTED ON SHORE
RUNNERS
45°
SCALE - 3/4" = 1' 0"
CUTTER ATTACHMENT W/REPLACEABLE BLADES
SIDE VIEW

WATERLESS DREDGE
(Waterless Dredging Co., Mattoon, Illinois)


16'
SIDE VIEW
7½'

DELTA MODEL 212 DREDGE
(Delta Dredging Co., St. Louis, Mo.)

Figure A-10A. Waterless and Delta Company Dredges

Table A-5. RECOMMENDATIONS FOR REDUCING TURBIDITY ASSOCIATED WITH PRESENT DREDGING PROCEDURES AND OPERATIONS

Cutter

Turn cutter as slowly as possible within confines of economical production. Slower speeds create less turbidity.

Use cutters properly designed for the job.

Suction

When material tends to flow naturally, remove cutters whenever possible to allow suction to be placed closer to the material.

Do not bury cutter unless all material will be picked up by suction.

Use a rotating suction assembly whenever possible. This permits using smaller cutters that create less material disturbance.

Ladder

Use properly designed ladders for each job. Do not use dredges with overly long ladders. Such ladders disturb material not available to the suction.

Hull

Keep dredge decks and all equipment clear and clean.

Use dredges with sufficient freeboard.

Use dredges of proper size. Hulls that are too wide, long, or deep create turbidity by hitting the sides and bottom of the cut.

Dredge Plant

Keep anchor wires free of soft bottoms and banks to prevent disturbance and caving of material.

Keep anchor barges and pontoons away from banks.

Use properly sized tenders. When tenders are not in use, disengage propellers.

Table A-5 RECOMMENDATIONS FOR REDUCING TURBIDITY ASSOCIATED WITH PRESENT DREDGING PROCEDURES AND OPERATIONS (CONT'D)

Pipeline

Keep pipeline connections tight, particularly on floating lines. Rotate lines to equalize wear.

Operational techniques

Use only the amount of set that will provide adequate material to the suction. Swing only fast enough to transport the material to the cutter.

Use proper methods of swing and set to pick up all material. Reduce necessity for cleanup where possible.

Personnel

Employ sufficient numbers of trained inspectors on all projects.

SILT CURTAINS

Silt curtains, turbidity barriers, or "diapers" as they are sometimes referred to, can be used to surround dredging or disposal operations as a means of containing or controlling the dispersion of turbid water created by the operation. Silt curtains, as shown in the following figure, are impervious vertical barriers that extend from the water surface to a specified water depth. They are especially effective in water where relatively quiescent current conditions are present. The flexible nylon-reinforced vinyl fabric, forming the barrier, is maintained in a vertical position by flotation material at the top and by a ballast chain along the bottom. An opening of 1 or 2 feet is left between the lower edge of the curtain and the bottom. This is done so that the vast majority of fine-grained material (possibly as much as 95 percent), which descends rapidly to the bottom and often forms a fluid mud layer, escapes with the flow of water under the curtain. Otherwise the curtain will be pulled under and buried by accumulating sediment. Therefore when the accumulation of fluid mud reaches the depth of the ballast chain along the lower edge of the curtain, the curtain must be moved away from the discharge.

PREDICTING AND CONTROLLING TURBIDITY

In maintaining and developing the waterways and harbors of the United States, the Corps of Engineers must annually dredge over 350 million cubic yards of sediment at costs approaching $200 million. To better define and evaluate the environmental impact of dredging, a 5-year dredged material research program (DMRP) was initiated in 1973. The primary goal of this program, which is being administered by the Environmental Effects Laboratory at the Waterways Experiment Station, is to provide more definitive information on the environmental impact of dredging and dredged material disposal operations and to attempt to develop technically satisfactory, environmentally compatible, and economically feasible dredging and disposal alternatives, including consideration of dredged material as a manageable resource.

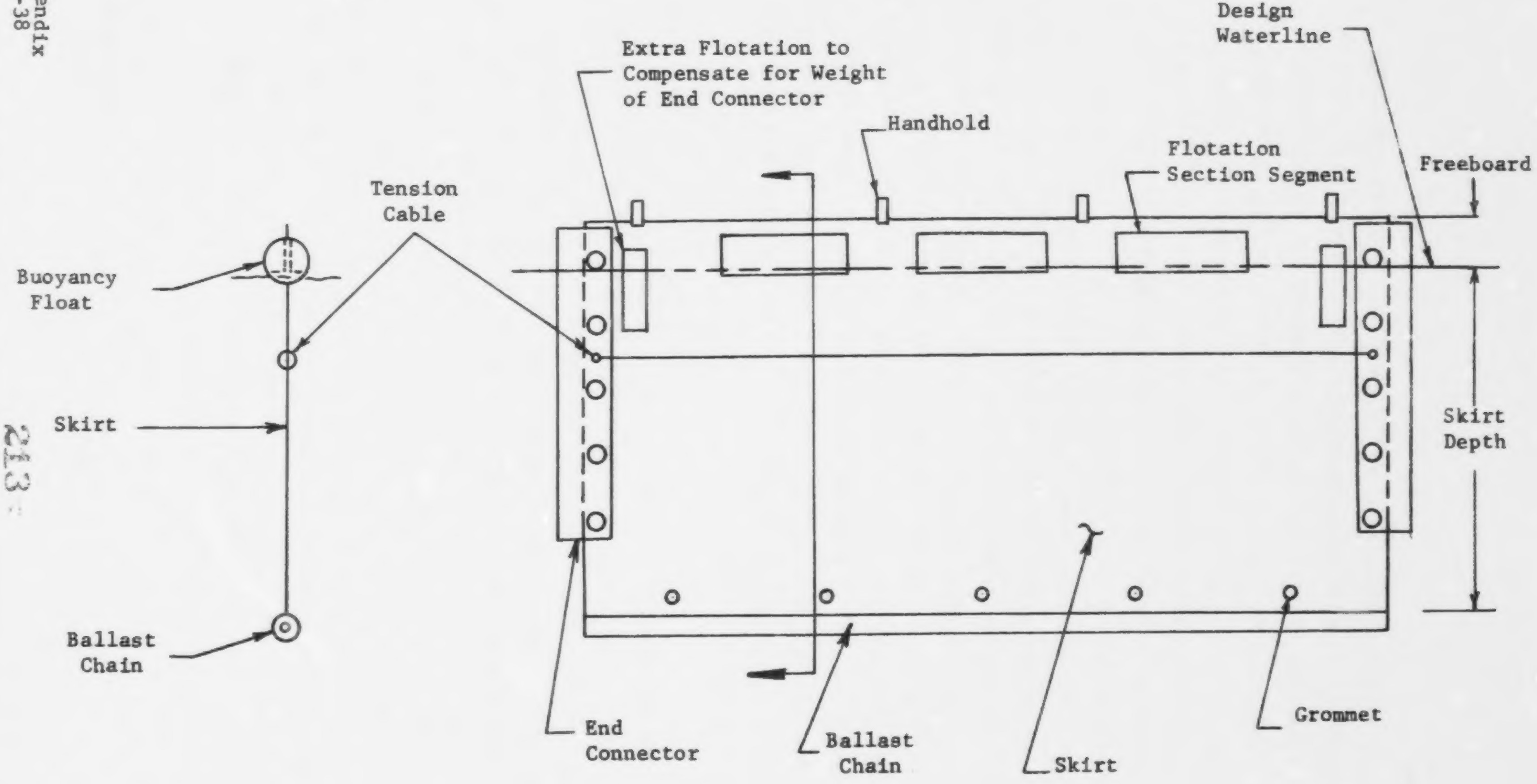

Design
Waterline
Extra Flotation to
Compensate for Weight
of End Connector
Handhold
Flotation
Section Segment
Freeboard
Tension
Cable
Buoyancy
Float
Skirt
Skirt
Depth
Ballast
Chain
End
Connector
Ballast
Chain
Skirt
Grommet

Figure A-11. Construction of a typical center tension silt curtain section (Waterways Experiment Station)

The following table presents some of the subjects that are being studied under this program. Reports thereon are scheduled for completion in 1978.

Table A-6. DREDGED MATERIAL RESEARCH PROGRAM OF THE U.S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION

Studies Underway
Aquatic disposal field investigations
Movements of dredged material
Effects of dredging and disposal on water quality
Effects of dredging and disposal on aquatic organisms
Pollution status of dredged material
Effects of marsh and terrestrial disposal
Nationwide survey of dredged material disposal sites in coastal wetlands area
Containment area operations
Confined disposal area effluent and leachate control
Upland disposal concepts development
Marsh development
Terrestrial habitat development
Land improvement concepts
Products development
Aquatic habitat development
Island habitat development
Dredged material densification
Disposal area reuse
Disposal area land use concepts
Treatment of contaminated dredged material
Turbidity prediction and control
Research results applications

DREDGING TECHNOLOGY IN CANADA

Canadian dredges are similar to those in the United States. They include such hydraulic dredges as the cutterhead and plain suction pipeline as well as hopper dredges. Over the past 2 years, the Public Works Department of Canada has tested a conical shaped cutterhead instead of the standard round basket type of cutter in sand and silty materials. Available data indicate that the conical cutter, with its lower peripheral velocity resulted in less turbidity. However, according to the Canadian engineers, an equal reduction in turbidity may be achieved with the regular basket type of cutterhead by reducing the revolutions per minute of the cutter.

DREDGING TECHNOLOGY IN EUROPE

GENERAL

Dredges in use can be divided into three basic types:

a. Mechanical, such as the bucket, dipper, and grab dredges;

b. Hydraulic, such as the stationary suction, the hopper, and the barge unloading dredges;

c. Pneumatic, such as the Pneuma dredge.

MECHANICAL DREDGES AND BARGES

The bucket dredge is a very popular type of dredge in Europe because it can handle many types of material. It also has the capability to load barges; this is an important factor since dredged material usually has to be transported over long distances to a disposal site. Most bucket dredges are of the pontoon type and are now self-propelled. The barges are unloaded either by dumping or by a barge unloading dredge that pumps the material ashore.

Most grab bucket dredges are of the pontoon type equipped with one grab. In the United Kingdom the self-propelled grab hopper dredge is popular and generally equipped with one to four cranes.

The barges can be nonpropelled as well as self-propelled vessels. The nonpropelled barges are normally towed by tugboats, but more and more barges are being built to be transported by push boats. Three types are available:

a. Elevator barges without bottom doors,

b. Hopper barges with bottom doors or valves, and

c. Split barges.

The split barge has the capability to unload soils such as clay, with more control than the traditional dump barges.

In Europe the barge unloading dredge, also called reclamation dredge, is used mainly to empty barges and to pump the dredged material into reclamation areas. Dredges are equipped with water jet pumps, and the most powerful dredges can pump dredged material over distances of 9,000 feet and more. Some of these dredges are constructed in such a way that they can be converted into a stationary suction dredge.

HYDRAULIC DREDGES

As in the United States, the stationary suction dredge is equipped with a plain suction pipe which sucks loose material from the bottom. The flow of material toward the suction pipe is often increased by the application of jets. The dredged material is discharged either via a floating pipeline or into barges hauled alongside. A report on European dredging activities states that, if operated carefully and at a reduced output, the turbidity created by a suction dredge is of the same magnitude as for the Pneuma type dredge described in later paragraphs.

The cutter suction dredge is equipped with a rotating cutterhead at the end of the suction pipe. During the swinging motion of the dredge, the cutterhead loosens the in situ material and transports it toward the suction opening. This type of dredge is very popular all over the world. The advantages of this dredge are:

a. The dredge has a wide scope of possibilities with respect to soil conditions.

b. The dredge prepares a fairly level bottom and can also provide for appropriate slopes.

The trailing suction hopper dredge, also called draghead dredge, is used throughout Europe for maintenance in ports, port entrances, and port approach channels. The dredges have a capacity from 800 to 18,000 tons. Smaller units usually have one trailing pipe and the larger units are equipped with two. Almost all dredges are equipped with bottom doors. Some can also discharge their load overboard either at sea or into a disposal area.

PNEUMATIC DREDGES

Pneuma Dredge. The Pneumatic International S.A. of Italy has developed a system operated by compressed air for dredging sand, gravel, mud, silt, or clay. It includes three steel cylinders usually of the same section and height. At the bottom of each cylinder is one entrance pipe for the mixture; at the top is a pipe for the introduction and release of compressed air and a second pipe for removing the mixture. The latter pipe extends almost to the bottom of the cylinder. In each cylinder there is a valve above the entrance pipe.

According to the Pneuma brochure, the work cycle of the Pneuma pump can be divided into three phases:

Phase 1--Filling the cylinders. Each cylinder is filled with a mixture of water and silt, sand, mud, etc., by a counter pressure due to the hydrostatic head when the pneuma cylinders are immersed in water. As soon as one cylinder is filled, the inlet valve automatically closes by its own weight.

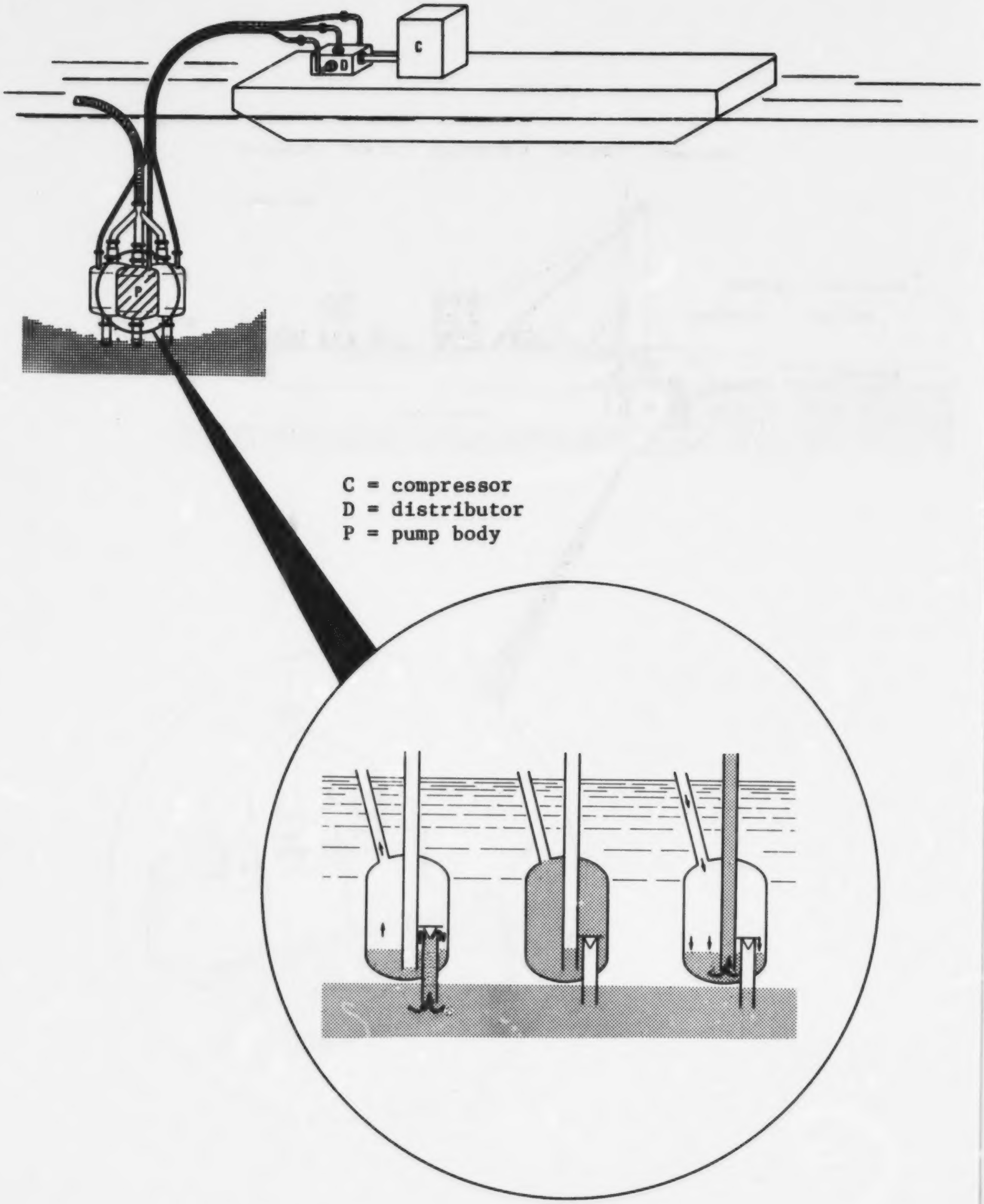
Phase 2--Emptying the cylinders. When a cylinder has been filled, compressed air, supplied by a compressor through the distributor and air hose, acts as a piston and forces the mixture to be expelled from the cylinder to the delivery pipe.

Phase 3--Discharging compressed air and preparation for phase 1. When the cylinder has been almost emptied, the distributor discharges the air into the atmosphere. Once the internal pressure is released, the inlet valve opens and the cylinder once again becomes filled with the mixture, as described in phase 1.

The delivery pipe for the mixture widens just above the cylinder so that it can receive a spherical nonreturn valve. Whenever the pressure from the cylinder drops to let in a new mixture, the delivery pipe is automatically shut off so that the mixture cannot flow back into the cylinder.

The distributor is situated between the compressor and the pump body, on the ground near the compressor, or under water near the pump body. It regulates the inflow and discharge of compressed air to and from each cylinder of the pump body and assures uniform functioning and a continuous flow. Compressed air from each cylinder is discharged directly into the atmosphere or a large part is recycled by the compressor. In order to provide a continuously uniform delivery flow, the distributor acts alternately on the three cylinders with an average of one to three cycles per minute.

The air compressor is driven by any type of motor. The Pneuma pump therefore works as a piston pump, the difference being that the piston is formed by compressed air. Photographs of the Pneuma pump follow.



C = compressor
D = distributor
P = pump body

Figure A-12. Pneuma Pump Dredging System

(Pneumatic International S.A., Italy)

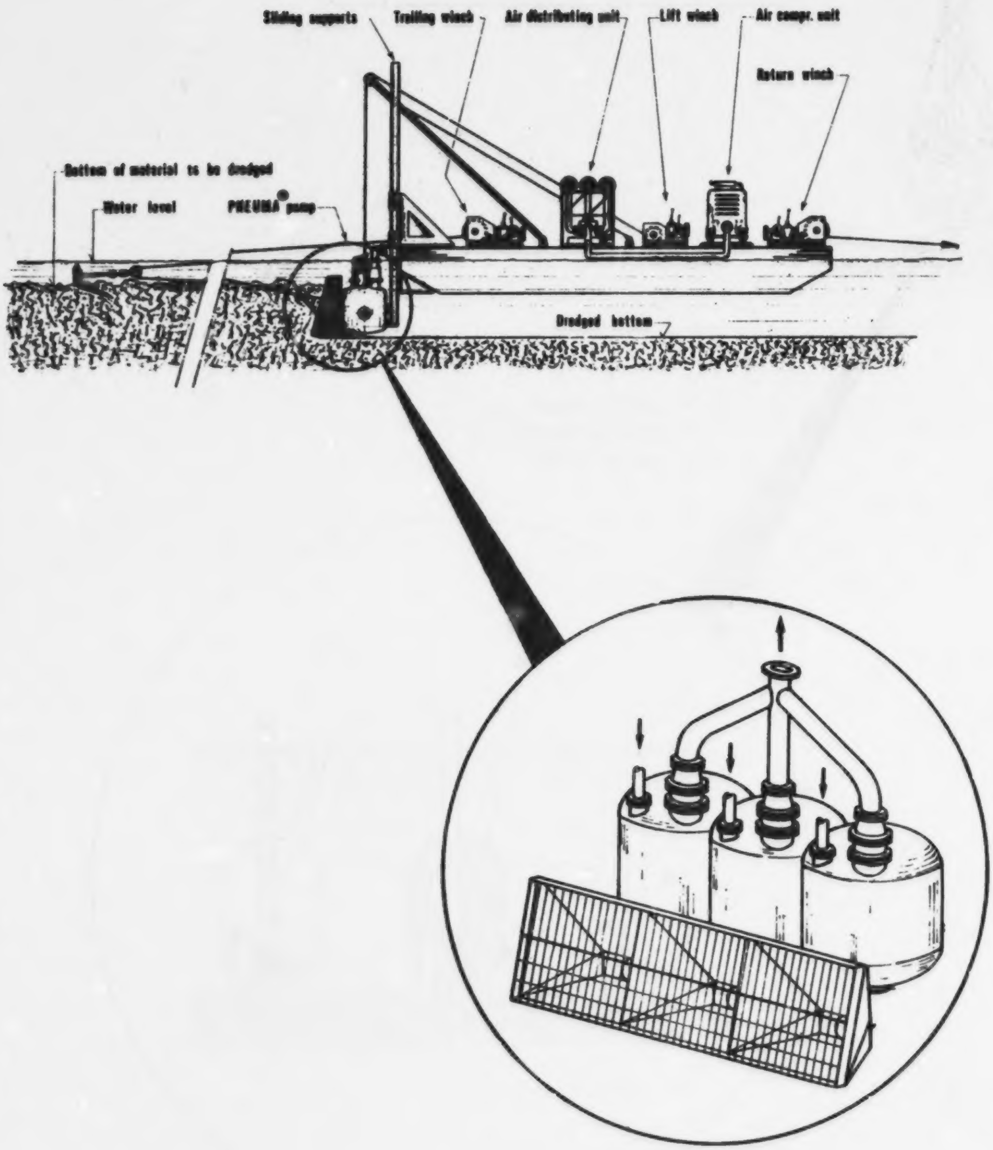

Sliding supports
Trailing winch
Air distributing unit
Lift winch
Air compr. unit
Return winch
Bottom of material to be dredged
Water level
PNEUMA® pump
Dredged bottom

Figure A-13. Pneuma Pump, Trailing System

(Pneumatic International S.A., Italy)

According to the manufacturer, some of the advantages of the Pneuma system follow:

a. Continuous and uniform flow.

b. Practically no wear since there are no mechanisms in contact with the abrasive mixture except for the self-acting spherical rubber valves.

c. Percentage of solids up to 60 to 80 percent by volume are possible. This high concentration of solids in the dredged mixture allows obtaining a considerable saving of water in the case of hydrotransport when dredging lakes or basins, or wherever it is necessary to save water.

d. Particularly suited for dredging polluted materials since it does not disturb the bed while dredging and therefore avoids secondary pollution.

e. Can be readily dismantled for transport over highways.

f. Perfect levelling of the bottom without excavating more than the required section.

g. Possibility of installing the Pneuma dredging plant on any type of existing watercraft without the need of constructing a special pontoon.

The pump body, illustrated on a previous page, is of the standard type with three cylinders grouped together. The inlet valves beneath can be connected to a "levelling shovel" by means of curved pipes of a determined diameter. To obtain maximum solid content in shallow water where the hydrostatic head is low, the problem consists of facilitating the collection of the material by the pump. This is done by trailing the pump and forcing the material to penetrate through a shovel equipped with fixed blades into the cylinders as it is dragged forward, as shown on one of the photographs.

It is possible to reach a very high solid content in the mixture using the system described above, according to the manufacturer. This is due to the fact that the shovel is equipped with fixed blades which cut the material into strips allowing it to be pushed inside the pump body by the hydrostatic head. Such a high solids concentration makes transport by barge economical, particularly when the discharge distance is great. Similar efficiency can be obtained when dredging polluted material. Furthermore, the Pneuma system provides a distinct advantage over traditional dredges in that it does not create secondary pollution by disturbing the material on the bottom as the fixed blades cut into the material at a low advancement speed.

There seems to be a possibility for the system to operate effectively in shallow water because of the low power requirement. One problem that may arise is the possibility of foreign bodies, such as trash, becoming lodged in the cylinder. Oblong shapes, in particular, are unlikely to be pressed out.

One advantage of the system is that there are no moving mechanical parts in the pump. The three nonwearing rubber valves work automatically under the influence of pressure changes, opening and closing one to three times a minute. The air distributor unit is a very slow-moving, sturdy piece of equipment. The most vulnerable components are the flexible air hoses between the distributor and the pump.

__Pressair Sand Pump Dredge__. One company has developed dredging equipment that is operated by compressed air. It is shown in the two figures which follow.

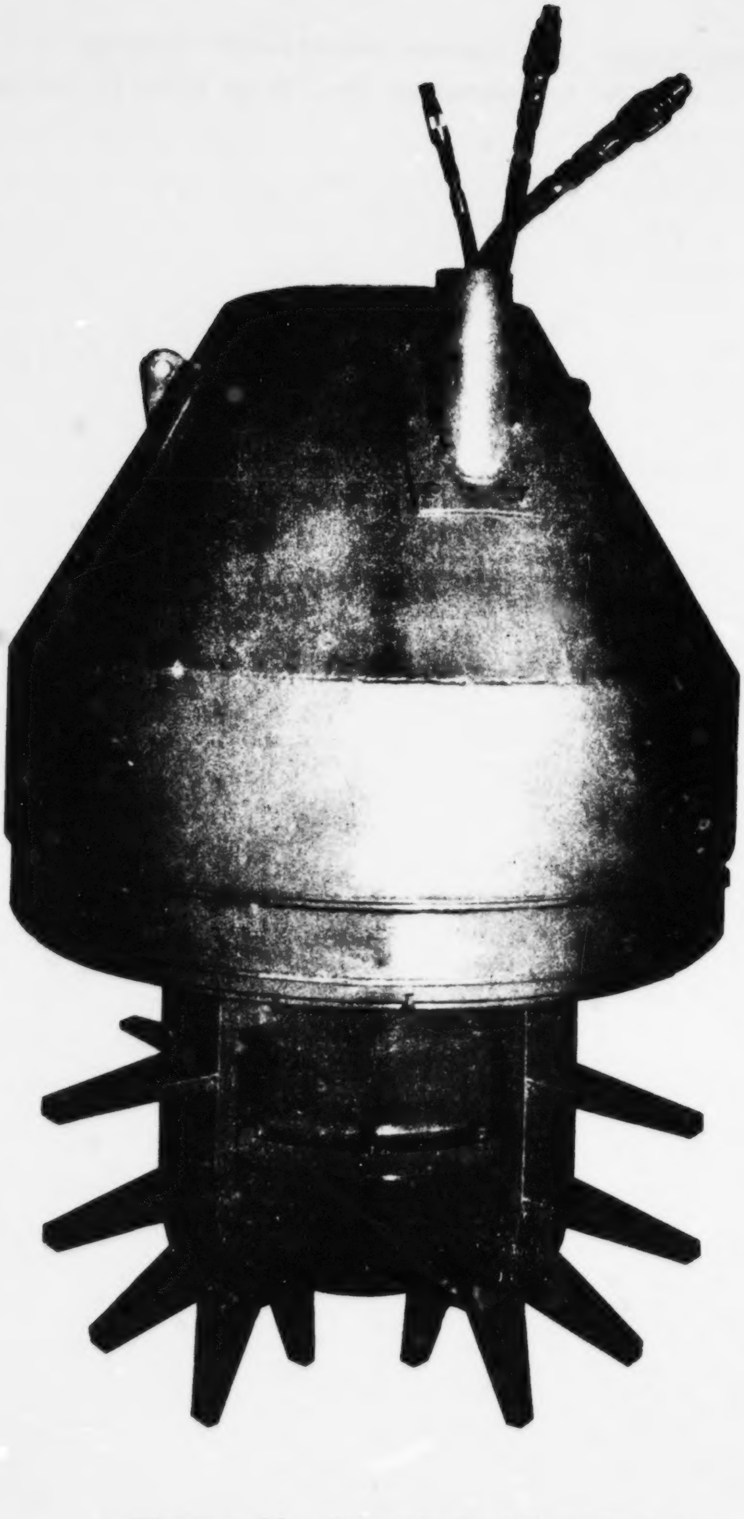


Figure A-14. Pressair Sand-Pump Dredge

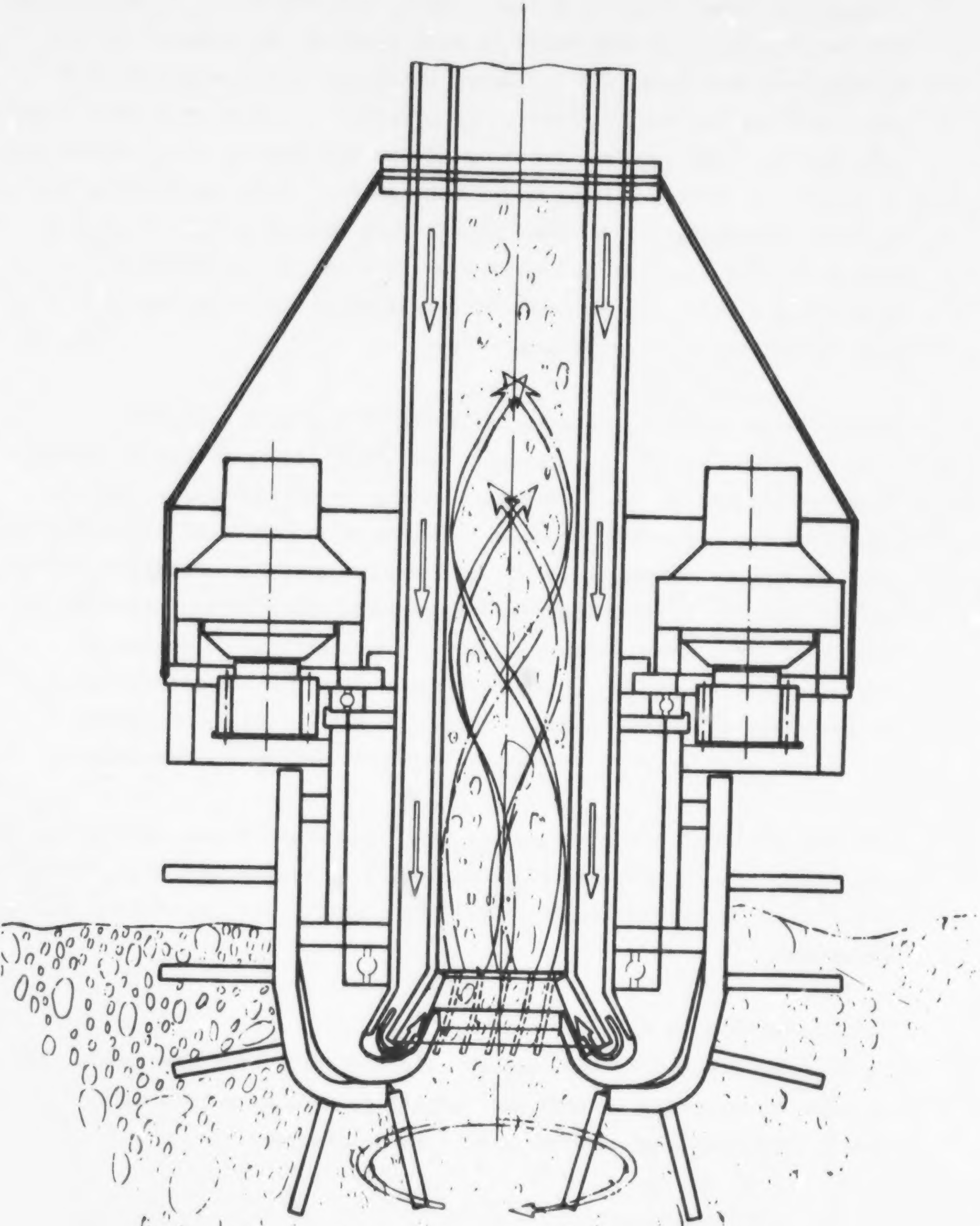


Figure A-15. Cutaway of Pressair Dredge

Through the outer shell of a double tube, compressed air is forced into the suction pressure head which is positioned on the bottom. In the suction pressure head, air is forced through a nozzle pipe into the lower part of the suction head. The hydrostatic pressure at this point then becomes less than the pressure of the surrounding water, resulting in an upward suction which conveys the material to be dredged and the water to the surface. By means of riffling (corrugating) of the air nozzle, a rotary motion is imparted which sucks up the material uniformly, even in the presence of sediments of differing specific gravity and various bottom conditions.

Consolidated sediment, as well as layers of clay, is loosened or penetrated by the suction pressure head which can pivot and is fitted with cutting teeth. The lower part of the head is shaped so that it cannot become clogged by wood, erratic stone blocks, etc. According to the company, the application of the Pressair Sand Pump Dredge operates well at greater (increasing) depths and with consolidated material. Layers of clay, which usually prohibit the exploitation of deeper deposits, are penetrated by the DSB head. The DSB head can be mounted on the majority of the customary grab (bucket) dredges. Dredging depths up to 80 meters (262 feet) below the surface are possible.

The Pressair-DSB, depending on the type and construction, dredges continuously up to 300 cubic meters per hour (approx. 400 cubic yards per hour). The installation is fully automatic. It is used for mining operations.

SHALLOW UNDERWATER BULLDOZER

In the last few years, underwater bulldozers have been developed. The shallow underwater bulldozer can operate in depths up to 5 meters (16 feet). The three main elements of this system are:

a. It is unmanned.

b. The power unit is installed on a self-propelled barge.

c. It has a connecting bar.

The air tanks are fitted to the bulldozer so that it can be immersed and lifted out of water again. The movement of the bulldozer can be watched by means of a mast mounted on the bulldozer. From this mast the inclination, depth, and direction of operation of the bulldozer can be determined. The air and oil delivery pipes are attached to the connecting bar of the barge and the bulldozer.

The underwater bulldozer has already been put to various uses in Japan and various tests have been carried out. In one harbor, it operated in hard clay for 90 days at depths between 5 and 20 meters. Loosening this material and piling it up, the output achieved averaged 105 cubic yards per hour. The heaps of clay were then lifted to the surface by a grab bucket.

IHC AMPHIDREDGES

A series of small dredging units have been developed by IHC Holland. They are designed for dredging under wet or marshy site conditions. They can be transported by truck or trailer. They include three kinds of dredging techniques--clamshell grab dredging, backhoe dredging (operates like a dipper), and cutter suction dredging. Included are the H series, the M series, and the S series. Photographs of amphidredges follow.

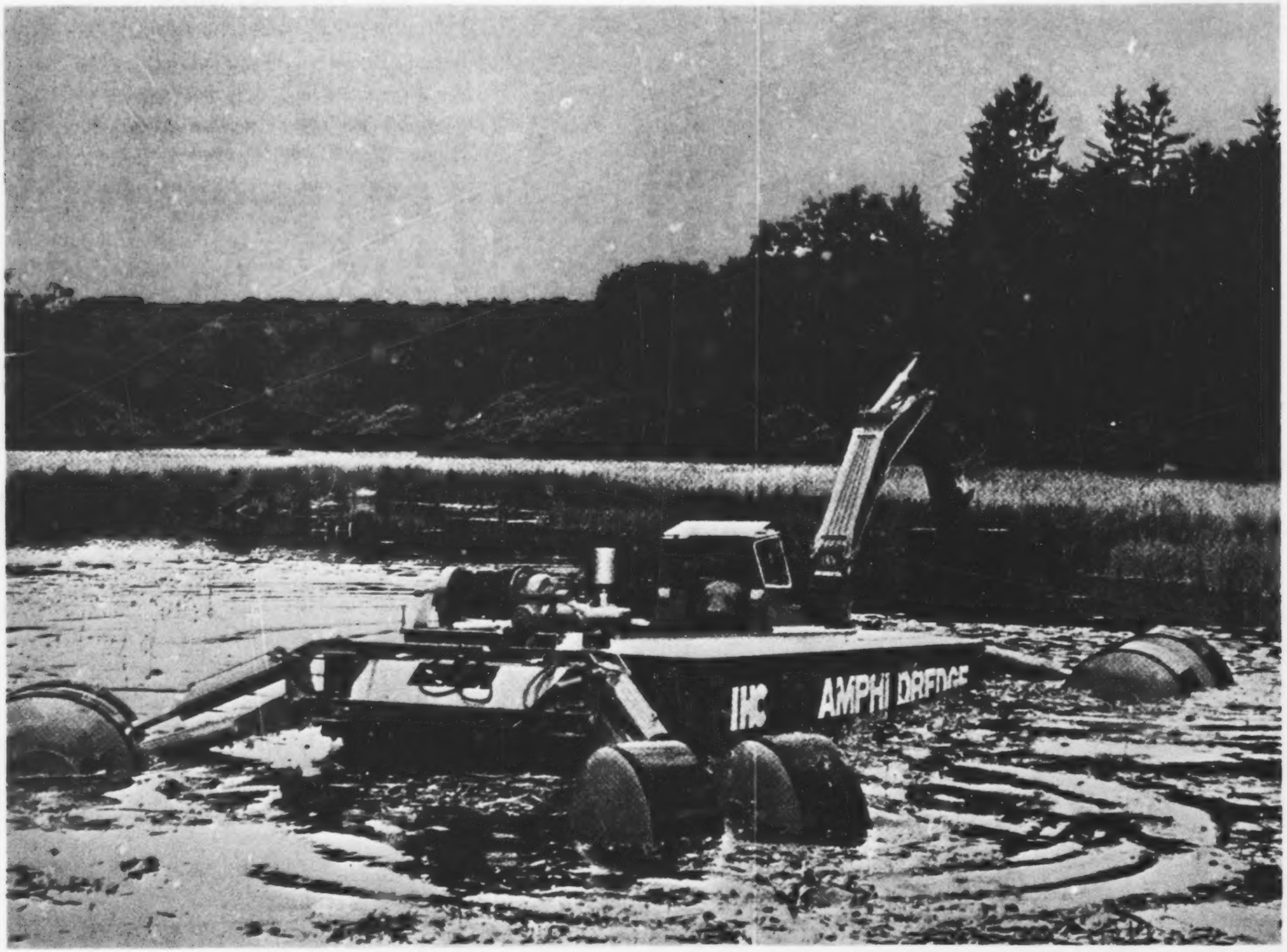

IHC
AMPHI DREDGE

Figure A-16. Amphidredge
(IHC Holland)

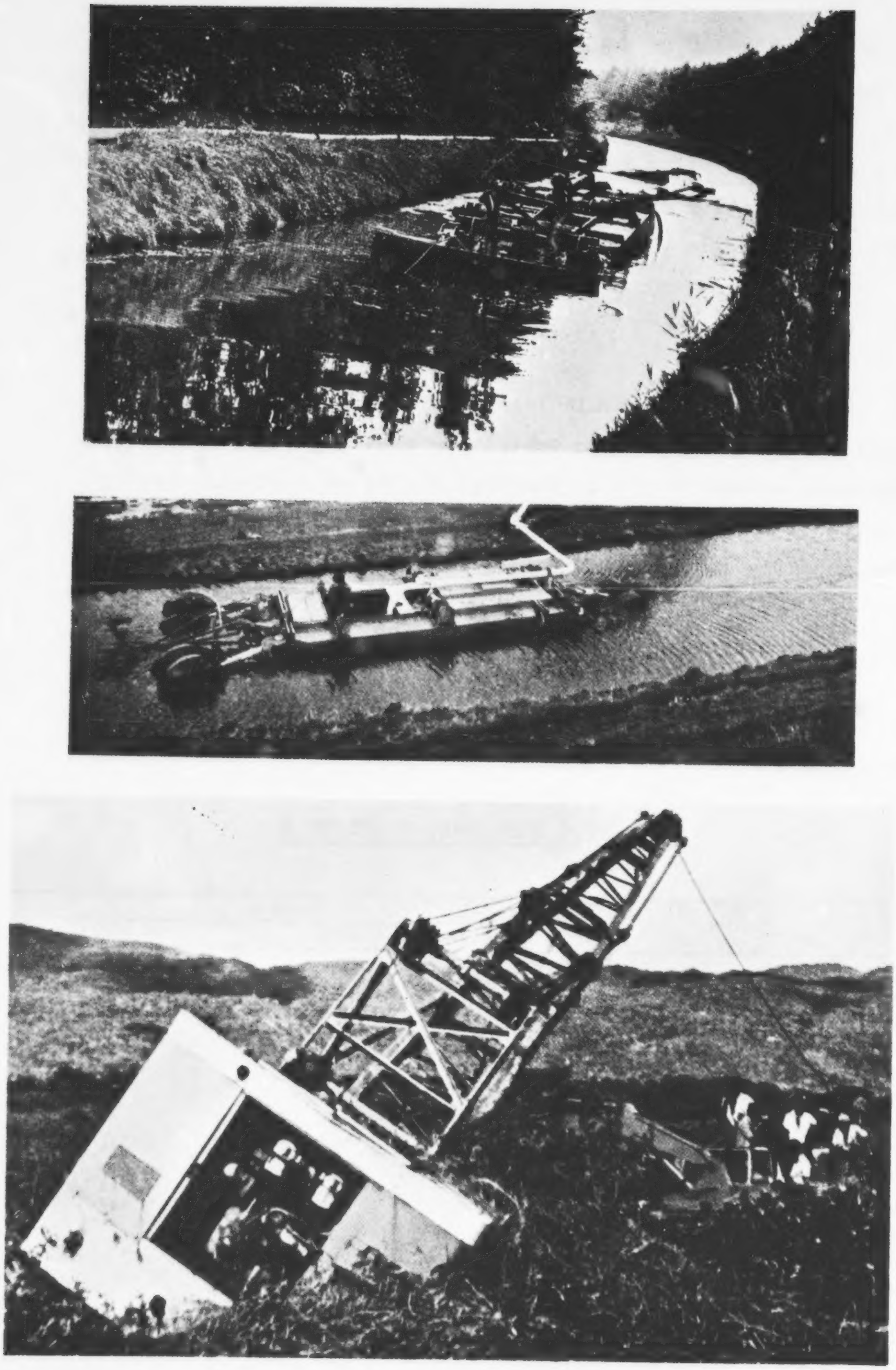


Figure A-17. Amphidredge Activities

(IHC Holland)

The H series equipment is amphibious. Each machine can move itself from land into water and vice versa. It can work on flat land, hilly terrain, in swamps, and in the water. Models equipped with four legs can move over steep hills and steep river or canal banks to reach the dredging or excavation site. Models equipped with three legs are somewhat restricted in this respect. Each machine consists of:

a. A main pontoon.

b. Three or four moveable legs, hydraulically operated, permitting displacement of the vehicle by crawling (like a turtle). The equipment stands firmly on the legs during excavating/dredging, which is the reason why these machines have such a remarkably high dredging capacity in relation to their size.

c. An excavator with backhoe, clamshell, grab, or mowing bucket.

The principal characteristics of the H series are summarized in the following table.

Table A-7. MINI DREDGE SERIES H

Item	Type of dredge H 150	 H 400-3	 H 400-4
Number of legs	3	3	4
Maximum reach of excavator; meters	5.0	6.7	6.7
Maximum dredging depth with backhoe, meters	2.4	4.5	4.5
Engine, horsepower	37.5	74	88
Weight, kilograms	5,500	12,000	14,000
Content of standard backhoe, liters	150	400	400
Minimum water depth			
for navigating, meters	0.7	1.05	1.05
for operating, meters	nil	nil	nil

The two M series consist of:

a. A self-powered mobile grab dredge crane that can operate from land and from water when installed in the floating pontoon system. The crane is also used to put this pontoon system and the auxiliary equipment into the water and back again on trucks after completing the job.

b. A floating pontoon system to carry the grab dredge crane when operating from the water.

The principal characteristics of these machines are as follows:

Table A-8. MINI DREDGE SERIES M

	Type	
Item	M 350	M 500
Length of standard boom, meters	9	11
Engine, horsepower	31.5	31.5
Weight, kilograms	13,700	14,000
Content of standard grab, liters	350	500
Minimum water depth required, meters	0.5	0.5

The S series machines all employ a milling cutter suction system developed in Holland especially for the maintenance dredging of silt and organic sedimentation. This system uses the pumping principle rather than the excavating principle. The milling cutter suction system consists of:

a. A milling cutter scoop for funnelling the silt or other loose deposits into the direction of the suction opening, thereby increasing the solids/water ratio.

b. A milling cutter device for cutting vegetation, small branches, large hard pieces of deposit, etc., and at the same time mixing all these components into uniform slurry, thereby enhancing the performance of the pump.

c. A special pump with an impeller able to handle relatively large pieces of debris such as food cans, shoes, bricks, etc., thereby minimizing down time due to clogging of the pump.

Milling cutter suction dredging is done by winching the boat forward along a guiding wire rope. On the bigger S-200, additional steering is provided by a disc wheel on its aft legs.

The S series amphidredges can be outfitted with three or four legs so that they can turtle walk on their own power from the transport vehicle over land into the water and, when on site, around small bridges and other obstacles.

The principal characteristics of these machines follow:

Table A-9. MINI DREDGE SERIES S

	Type	
Item	S 170	S 200
Maximum dredging depth, meters	5.00	5.35
Production, cubic meters/hour	50-80	100-140
Diameter, suction pipe, mm	170	200
Engine, horsepower	110	165

Maintenance dredging of silt and vegetational sedimentation can be done with an amphidredge H, M, or S machine. In most cases, the S machine will do this work most economically, unless the following conditions prevail:

- The silt is filled with too much debris or there is heavy vegetation.

- The spoil can be dumped directly on land by an H or M machine, so that no other spoil transporting equipment is needed. When those conditions prevail one or more H or M machines, in conjunction with auxiliary equipment, could do the work more economically.

USE OF DISPOSAL AREAS

Disposal areas in Western Europe are used for productive purposes without exception. The most common destination is in harbor or industrial areas. The relatively low bearing capacity is no problem as, in most cases, pile foundations for buildings and structures would normally be required. Other productive destinations of disposal areas are agricultural and/or recreational. Except for investigations in Rotterdam, no other scientific analysis of the influence of contaminants on plants seems to have been carried out in Europe.

The area to be reclaimed is either a low-lying polder or wasteland, which, apart from serving as a disposal site, would benefit from an increase in elevation. In confined disposal areas, dikes are constructed prior to commencement of the reclamation. Proper attention is paid to the soil mechanics aspects of the dike construction, and stability is checked regularly during the reclamation process. Excess water entering the disposal area along with the dredged material is discharged through an outlet system. Depending on the quality of the effluent (salinity), special measures may have to be taken to avoid intrusion of brackish water into a freshwater system. After the filling of a fresh layer and the drainage of free water, measures are taken for rapid dewatering of the dredged material. Gradually the "ripening" process is initiated whereby the dredged material is converted into ripened soil, which is accessible and useful for various purposes. From this moment onward, the dikes are raised by making use of the reclaimed soil and another layer of material is placed in the area. Layers are 2 to 3 feet thick. In this way, the process can be repeated several times. The number of layers depends on the intended height of the disposal area, the quantity of dredged material to be stored, the time until the land is needed for its ultimate purpose, and the grain size of the material.

As previously stated, the dredged material in disposal areas has the character of "unripened" soil. This term refers to the properties of fresh mud settled in water. For such material to become suitable for use, it must go through a ripening process. The ripening process consists of removing the water which, in turn, causes the distance between the grains to diminish and the overall volume to reduce or subside. The volume reduction leads to cracking, enabling air to reach the sediment. The slushy mud in time becomes solid soil and with increased ripening salts are leached, encouraging root growth. Ripening is a very long, drawn-out process, often taking many years. Various artificial means are at times utilized to reduce the time.

CONTAMINATION OF DREDGED MATERIAL

Until 1970 salt intrusion was the only environmental effect which was taken into consideration in Europe. About this time several European countries started discussing the environmental effects of the pollution of the sea by substances that are liable to create hazards to human health or marine life. About 1972 some harbor authorities initiated surveys into the presence of contaminants in dredged materials. Thus far it appears that no criteria are available from which the quality of dredged material can be judged. At the present time there are no legal standards in force in any European country for soil pollution by heavy metals because scientific investigations designed to identify the upper limits are still in process.

The Rhine River is often described as the sewer pipe of Europe because of the enormous quantities of industrial wastes discharged into the river. Heavy metals form an important part of these wastes. The larger part of the discharge of heavy metals is bound to the silt load of the river. A 1970 study of silt movement in the southern part of the North Sea used heavy metal content as an indication for the origin of the sediment. It was found that heavy metal content of the sediments from several rivers varied considerably.

Comparing the technical developments in Europe with those in the U.S.A., some differences can be noticed. There is practically a complete absence of bucket ladder dredging in this country, while this type of equipment is considered a very suitable one for maintenance dredging in Europe.

This is mainly because a relatively high solids concentration can be achieved in soft, fine sediments. The concern about the contamination of dredged material with heavy metals, pesticides, and other pollutants is common in this country and in Europe. Insofar as disposal on land is concerned, the only concrete information available at this moment in Europe is the fact that care is recommended with respect to human consumption of agricultural products grown on contaminated material in disposal areas. The United States and Japan have generally surpassed the Europeans in determining the pollution potential of dredged material.

DREDGING TECHNOLOGY IN JAPAN

In recent years, Japan has achieved rapid economic progress. However, the environment surrounding the manufacturing enterprises has deteriorated to a marked extent. Waste water from factories and industrial wastes have produced sludge that has contaminated the sea. Toxic substances present in the sludge have destroyed the environment, and local fisherman have been obliged to change or abandon their occupation. Settling of the sludge also hindered the passage of ships. Thus the social problem became serious.

Accordingly the Japanese have undoubtedly concentrated on improving the dredging technology for avoiding resuspension of sludge-like sediments more than any other country in the world.

CARE IN DREDGING HAZARDOUS MATERIAL

According to Mr. Kasuyoshi Nishi, (see references) the dredging of sludge must be preceded by careful investigations of the natural conditions at the work site and the properties of the sludge to be disposed of. This is necessary to minimize the extent of secondary water contamination, assure safety of the operation, avoid affecting the condition of sludge on the seabed, and finally raise work efficiency and economy.

Extraordinary care has to be taken with hazardous sludge materials which might have undesirable influences upon the environment. According to Mr. Nishi, the following criteria should be applied to the dredging of such sludge:

a. Prevention of sludge dispersion by every means possible,

b. Dredge sludge only, without affecting the seabed below, and

c. Dredge sludge in high density condition, if at all possible, so as to lower the overall work cost, including expenses for the subsequent filling in of the reclamation site and conditioning of the sludge. (Actually the sludge has a low in situ density in that 90 percent is water by weight.)

DREDGING TECHNIQUES

According to a paper by Messrs. Koba, Shinohara, and Sato, (see references) it is stated that the technique for managing toxic sediments deposited in the ocean or rivers has not been thoroughly developed as yet. There are a small number of examples in Japan which primarily involve removing these sediments by dredging. The ability to judge any dredging techniques that have been developed to date and the necessity for dredging based on the status of the sediment, as well as the various environmental conditions surrounding it, are still quite primitive.

Dredges which have been especially designed in Japan for moving sludge and now in active service are:

a. Modified cutterless hydraulic dredge. This includes the "Clean Up" dredge.

b. Anti-turbidity overflow system (IHI System) for hopper dredges.

c. Oozer Pneumatic dredge.

d. Watertight grab bucket.

Available data on these systems are presented. Similar studies of other equipment are also undoubtedly in progress.

CLEAN UP HYDRAULIC DREDGE

The cutter suction dredge, with the rotation of the cutter at the suction mouth, creates turbidity and secondary pollution. Thus the purpose of dredging hazardous material from the sea bottom cannot be attained if resuspension of the sediment takes place in the dredging area.

In his paper (see references), Mr. Eisuke Sato states that the traditional belief relative to the suction equipment of dredges is that materials are led into the suction mouth by water currents located beyond the suction head. Instead, Mr. Sato suggested that:

a. Suction equipment be considered as the collection equipment for sediments. This is based on the concept that it is better to (1) intercept water currents outside of the suction equipment and (2) guide sediments into the equipment in their undisturbed condition.

b. From the viewpoint of pollution, it is also desirable for the collection equipment to include a moveable wing system that can overlie the area being dredged.

c. It is necessary to have a proper mixing device in the suction equipment that will mix the sediment and water into a uniform slurry.

d. It is desirable for the suction equipment to maintain contact with the bottom sediments. In order to satisfy this requirement, the suction equipment has to be equipped with a horizontal controlling device which keeps the equipment in contact with the sediment even if the dredging depth or other conditions change.

In order for the suction equipment with the above functions to operate most efficiently, it is necessary to monitor the material flow, collection process, and condition of sediments in front of the dredge.

It is also necessary to check the turbidity generated by dredging. By installing sensors to check the dredging conditions, the most suitable operating conditions can be maintained by the operator of the dredge.

The Toa Harbor Works, of which Mr. Sato is chief of the mechanical department and sectional chief of the research and development department, has developed a new piece of equipment referred to as the Clean Up. The dredge itself looks like a conventional hydraulic cutterhead except for the Clean Up head installed on the ladder. It is equipped with:

a. A moveable wing or shield in front of the equipment so as to overlie the bottom sediments;

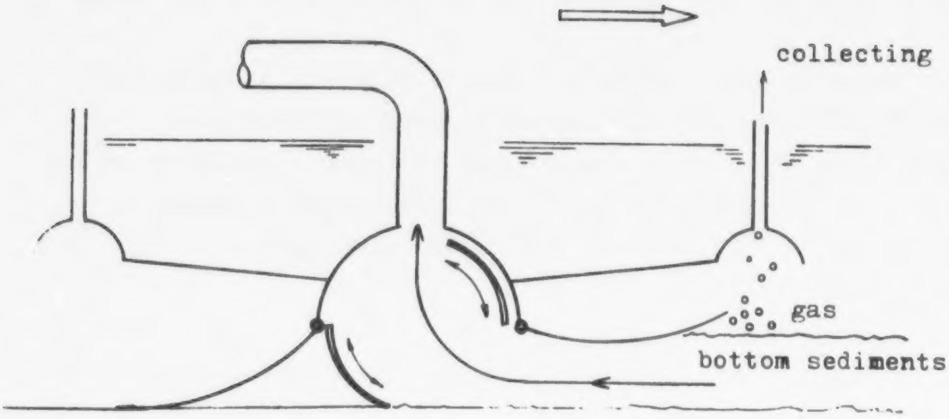
b. A moveable shutting plate which intercepts the flow of outer water;

c. An auger contained in the equipment that mixes and moves material to the suction pipe;

d. A device for collecting gas released during dredging;

e. Sonar devices to indicate the elevation of the material before and after dredging.

The Clean Up is also equipped with an underwater television camera. The equipment is used solely for clean up operations of highly contaminated, low density, sludge-like sediments. Photographs thereof follow.


collecting
gas
bottom sediments

Sediments enter dredge in original state. Movement is slow with no disturbance in the water. Sediments are removed in a high density condition. Noxious gas is collected.

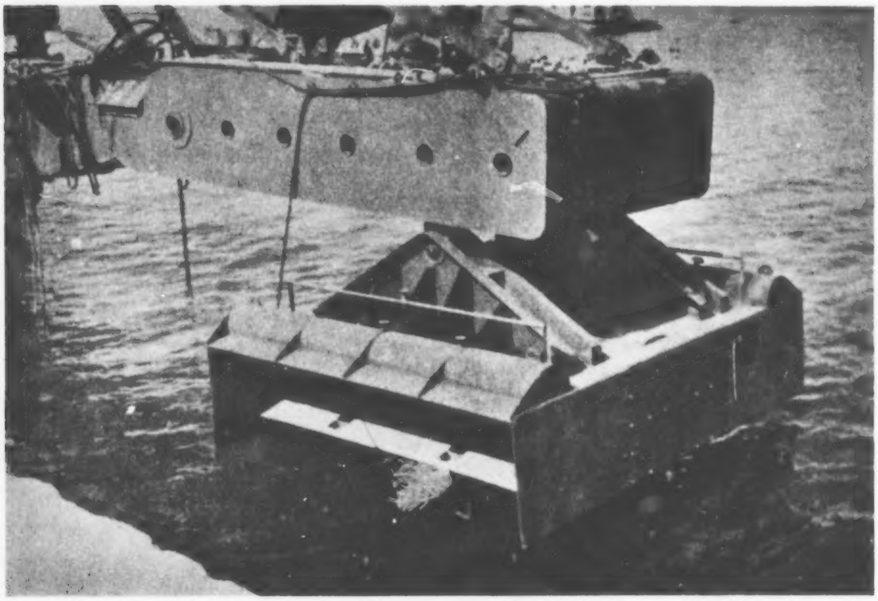


Figure A-18. Clean Up Dredge

(Eisuke Sato, Courtesy of WODCON VII)

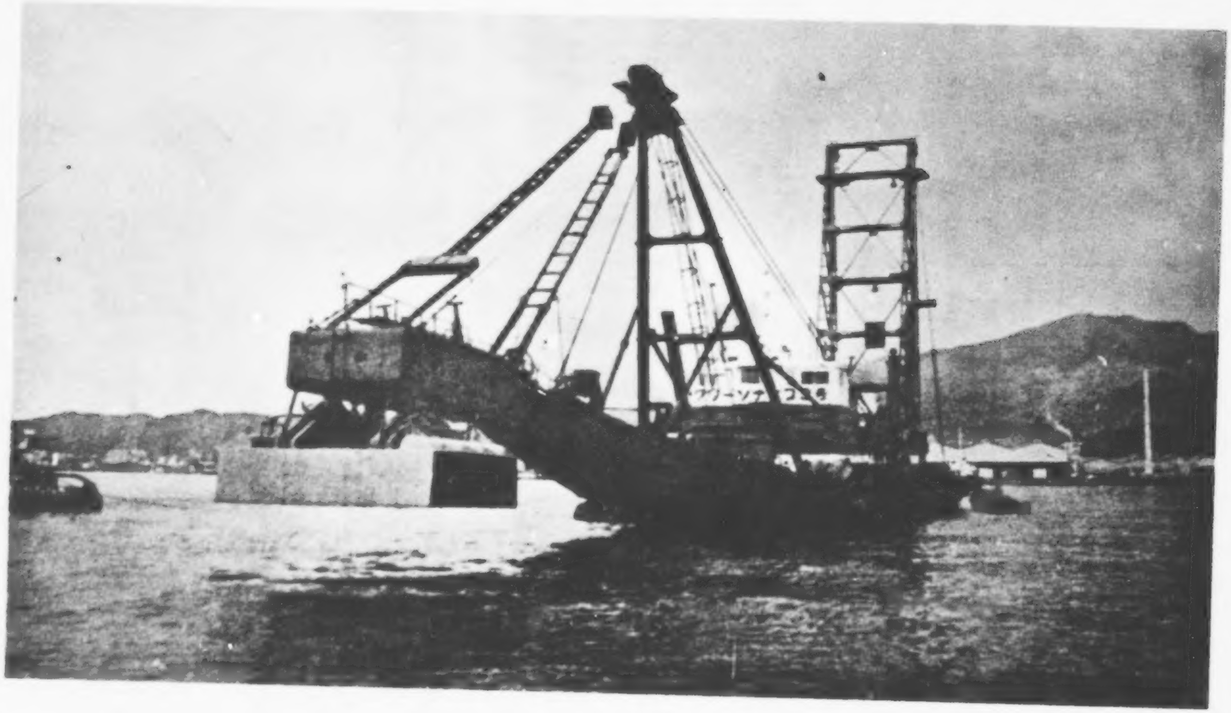


Figure A-19. Clean Up Dredge

(Eisuke Sato, Courtesy of WODCON VII)

The company has also determined that the submerged centrifugal pump is the most desirable pump for sediment dredging. The unit consists of a submerged hydraulic motor and centrifugal pump which has a large passage ability for rubbish and obstacles. The pump is designed so as to keep a constant rate of flow regardless of the change in sediment density.

The Toa Harbor Works has five Clean Up dredges; one is equipped with a Pneuma type pump while the others have submerged impeller type pumps. According to Mr. Sato the dredges must accomplish two goals:

a. Remove all required sediment, and

b. Minimize or eliminate turbidity or dispersion of suspended solids.

He has stated that the Clean Up system meets these requirements.

The following table is a list of jobs where the dredges have been used. Mr. Sato has stated that at most of the jobs the entire operation was monitored by the Government. The table indicates that Clean Up No. 1 has apparently operated in water with a depth of 1.5 meters (4.9 feet). Also the volume of material dredged in many instances has been small.

Data for Clean Up No. 3 dredge are:

a. Length = 42.7 meters or 140 feet.

b. Width = 13.0 meters or 43 feet

c. Depth = 3.3 meters or 11 feet.

Table A-10. ACTUAL RESULTS OF BOTTOM SEDIMENTS DREDGING WITH CLEANUP DREDGES
(TOA HARBOR WORKS CO., LTD.)

ORDERER	PLACE	PERIOD	DREDGER	DREDGING CONDITIONS							TOXIC SUBSTANCES
				AREA	VOLUME	DEPTH	LAYER	QUALITY	DISCHARGE LENGTH	QUANTITY	
No. 4 District Port Construction Bureau	Dokai Bay Fukuoka Pre.	Feb. '73	CLEANUP SIRSI 1/	1,000$^{m^2}$	1,000$^{m^3}$	-9.0^m	1.0^m	Silt	80^m	111$^{m^3/hr}$	Hg
Kanegafuchi Chemical Industry Co., Ltd.	Takasago East Port Hyogo Pre.	Sep. 27 '73 Oct. 20 '73	CLEANUP SIRSI	19,000	11,240	-4.5 -5.0	0.5 1.0	Silt and Clay	1,500	53	PCB 2/
Japan Fishery Resources Association	Yura Port Hyogo Pre.	Feb. 17 '74 Feb. 25 '74	CLEANUP SIRSI	2,400	473	-10.0 -11.00	0.22	Organic Compounds	(Barge)	38	3/
Mitsui Mining and Smelting Co., Ltd.	Nishiyama Port Yamaguchi Pre.	May 1 '74 Oct. 31 '74	CLEANUP SIRSI	46,200	58,000	-4.0 -5.0	1.25	Silt and Sand	300	23	Cd 4/
Otsu Paper Mills Co., Ltd.	Lake Biwa Shiga Pre.	May '74 Oct. '74	CLEANUP NO. 1	140,000	23,700	-1.5 -4.5	0.17	Pulp Sludge	887	74	PCB 5/
Japan Fishery Resources Association	Sagoshi Bay Hyogo Pre.	Oct. 18 '74 Nov. 24 '74	CLEANUP NO. 2	12,390	3,717	-3.0	0.30	Organic Compounds	250	35	6/
Yokkaichi Port Managing Office	Yokkaichi Port Mie Pre.	Mar. '75	CLEANUP NO. 2	3,432	2,712	-12.0	0.80	Oily Sludge	200	286	Oil (Hg.) 7/
Sumitomo Metal Industries, Ltd.	Wakayama Port Wakayama Pre.	Mar. '75	CLEANUP NO. 2	10,500	5,854	-12.0	0.56	Oily Sludge	(Barge)	100	Oil

1/ Pneuma type pump.

2/ Cleanup Sirsi, pipe transport, sedimentation pond, solidification. Treatment: Left to stand in sedimentation pond for 2-4 weeks. The supernatant water was discharged. Then the sediment was solidified (consolidated) with earth and sand.

3/ Cleanup Sirsi, barge, dewatering and grain formation, treatment, filtration, discharge.

4/ Cleanup Sirsi, pipe transport, reclamation land, flow, regulating channels, discharge.

5/ Cleanup No. 1, pipe transport, dewatering, solidification. Dewatering: filtration. Solidification: mixer.

6/ Cleanup No. 2, pipe transport, dewatering and grain formation, treatment, filtration, discharge.

7/ Cleanup No. 2, barge, reclamation land, filtration, discharge.

A-10. ACTUAL RESULTS OF BOTTOM SEDIMENTS DREDGING WITH CLEANUP DREDGES

(CONT'D)

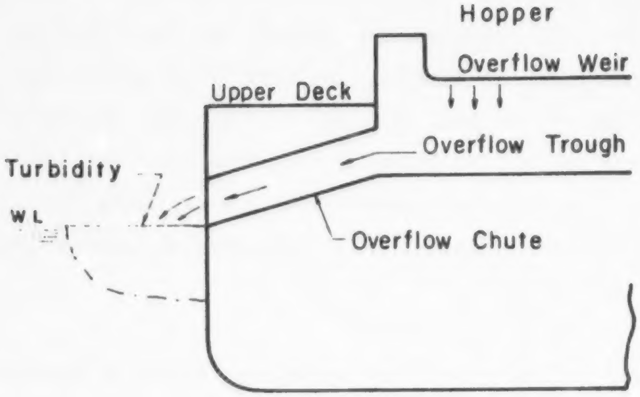
ORDERER	PLACE	PERIOD	DREDGER	DREDGING CONDITIONS							TOXIC SUBSTANCES
				AREA	VOLUME	DEPTH	LAYER	QUALITY	DISCHARGE LENGTH	QUANTITY	
Okayama Local Government	Tamashima Port Okayama Pre.	Mar. '75 Apr. '75	CLEANUP NO. 2	12,125	13,000	$-5.^{5}$	1.50	Silt & Sand	1,500	50	
Japan Fishery Resources Association	Aboshi Bay Hyogo Pre.	Aug. 25 '75 Sep. 30 '75	CLEANUP NO. 2	5,650	3,140	$-2.^{5}$	0.70	Organic Compounds	450	58	
Yamagata Local Government	Sakata Port Yamagata Pre.	Sep. 16 '75 Jul. 20 '76	CLEANUP NO. 1	30,000	48,700	$-6.^{0}$	1.50	Silt & Sand	870	49	Hg
Tokyo Port Construction Office	Takahama Channel Tokyo	Dec. 22 '75 Mar. 31 '76	CLEANUP NO. 5	2,793	2,100	$-3.^{5}$	0.75	Silt & Organic Compounds	130	98	
Nippon Mining Company Ltd.	Saganoseki Port Oita Pre.	May 10 '76 Oct. 9 '76	CLEANUP SIRSI	58,500	30,700	$-5.^{0}$	0.50	Silt & Sand	485	153	
Miyagi Local Government	Kesennuma Port Miyagi Pre.	Sep. 9 '76	CLEANUP NO. 2	42,600	21,300	$-3.^{0}$ $-7.^{0}$	0.50	Silt and Organic Compounds	200		
Yokkaichi Port Managing Office	Yokkaichi Port Mie Pre.	Nov. '76	CLEANUP NO. 3	700,000	2,200,000	$-5.^{0}$ $-20.^{0}$	1.0 5.0	Oily Sludge	6,000		Oil Hg

ANTI-TURBIDITY SYSTEM FOR HOPPER DREDGES

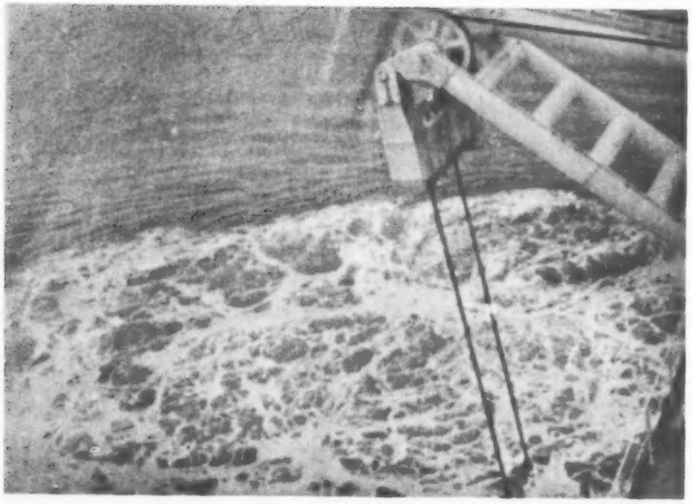
According to a paper by Messrs. Ofuji and Ishimatsu (see references), the overflow from hopper dredges results in turbidity caused by the overflowing water. In dredging operations, excess water in the hopper is discharged overboard continously as more sand and/or mud is sucked in from the bottom of the sea in order to increase the amount of material that the dredge is carrying and therefore its loading effficiency. As a result surrounding waters are made turbid by the excess water mixed with material, and currents and winds spread the turbidity over wide areas.

Messrs. Ofuji and Ishimatsu believe that the overflow system is indispensable for obtaining the highest dredging efficiency, thereby minimizing the dredging cost. Therefore they conducted model and dredging experiments to clarify the mechanism of turbidity and they have developed a simple and economical new overflow system which effectively prevents turbidity of the sea surface.

The following exhibit and photograph from their paper show the overflow system on a dredge and the turbidity caused by the excess water which overflows near the water line of the dredge. The next exhibit and photograph show the modifications resulting from model experiments, made primarily to suppress air bubbles and the accompanying turbidity created by the overflow process. In essence the overflow trough was divided into two parts to permit the overflowing water to remain in the trough long enough for the air bubbles to rise to the water surface and diminish. An inclined baffle plate was included. A gate regulating the flow was also provided in order to maintain the water level in the trough in a prescribed range.


Hopper
Overflow Weir
Upper Deck
Overflow Trough
Turbidity
WL
Overflow Chute

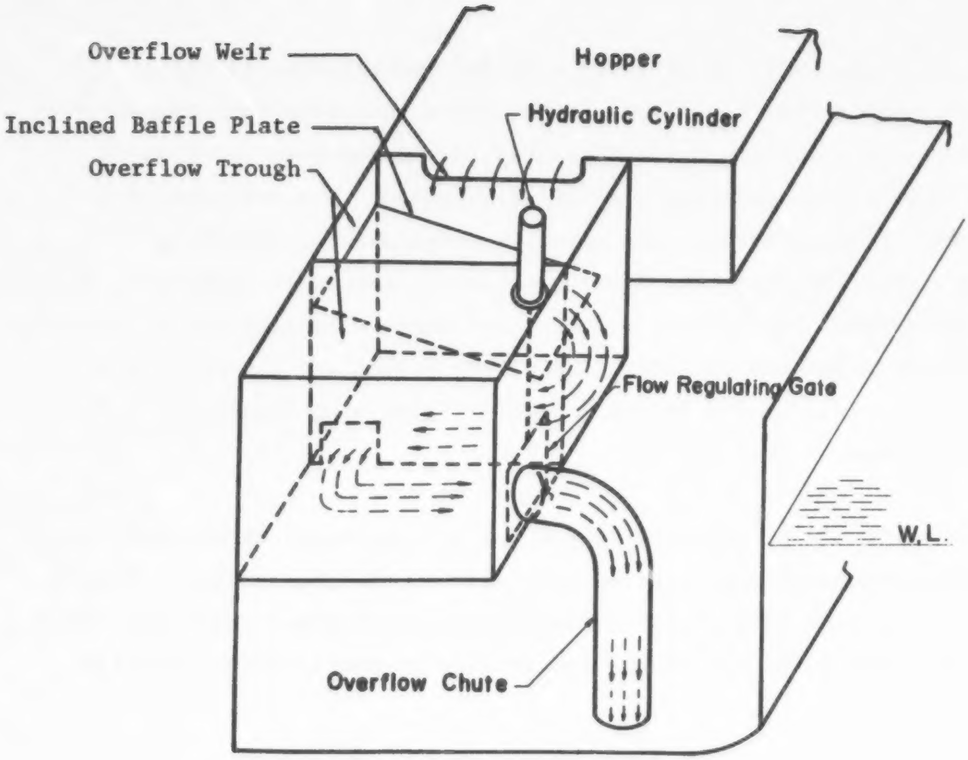
Original Overflow System
on Tokushun-Maru NO. 1



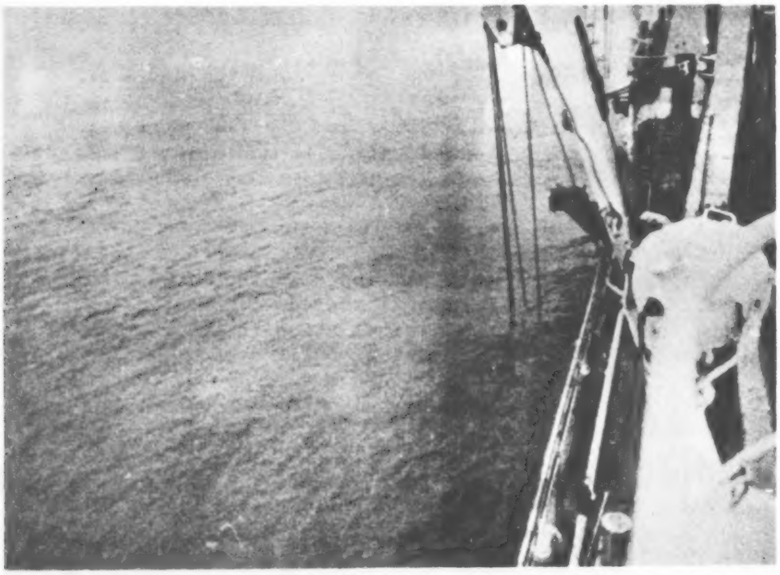
Before Improvement

Figure A-20. Anti-Turbidity Hopper Activities

247< (Ofuji and Ishimatsu, Courtesy of WODCON VII)


Overflow Weir
Hopper
Inclined Baffle Plate
Hydraulic Cylinder
Overflow Trough
Flow Regulating Gate
W.L.
Overflow Chute

Anti-Turbidity Overflow System developed by Ofuji and Ishimatsu



The clear sea surface under which the water mixed with silt and clay is being overflowed from KAIRYU MARU. The turbidity of sea surface is totally prevented.

Figure A-21. Anti-Turbidity Hopper Dredge Activities (Ofuji and Ishimatsu, Courtesy of WODCON VII)

The following table shows results of the installation of the Anti-Turbidity Overflow System. The table indicates that whereas the conventional overflow system resulted in a tremendous increase in suspended solids and reduction in transparency, the anti-turbidity system accomplished just the opposite--considerably improving conditions. The overflowed water is still discharged overboard, but it is submerged. The system, with its submerged discharge and appropriate baffling, maintains the integrity of the discharged slurry so that it settles rapidly to the bottom instead of remaining suspended in the water column.

The Anti-Turbidity Overflow System has already been installed in three hopper dredges without causing turbidity of the sea surface. The new system may also be applied to hopper barges and scows which are likely to cause the turbidity of the sea surface by excess water overflow.

Table A-11. QUALITY OF SEA WATER SAMPLED DURING ACTUAL DREDGING EXPERIMENTS WITH KAIRYU MARU

(SAMPLING SPOT: SIDE BY THE SHIP)

(Ofuji and Ishimatsu, Courtesy of WODCON VII)

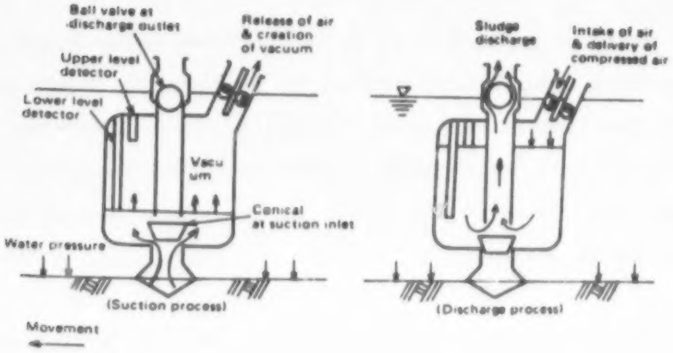
Test items	Test no.	Conventional overflow system				Anti-turbidity overflow system			
		Before overflow		During overflow		Before overflow		During overflow	
		Sea surface	1 M below sea surface	Sea surface	1 M below sea surface	Sea surface	1 M below sea surface	Sea surface	1 M below sea surface
Concentration of suspended solid (SS) (P.P.M)	1	9.0	8.0	370	370	3.5	5.0	8.5	10.0
	2	-	-	510	380	-	-	6.3	6.3
	3	4.5	10.0	85	190	6.5	6.5	1.6	6.3
	4	-	-	2000	410	-	-	7.0	6.6
	5	-	-	170	110	6.0	5.5	7.5	9.5
	6	-	-	-	-	-	-	5.0	10.5
	Ave.	6.8	9.0	627	272	5.3	5.7	6.0	8.2
Transparency (M)	1	1.25		0.30		1.70		1.80	
	2	-		0.40		-		1.90	
	3	1.40		0.30		1.60		1.80	
	4	-		0.05		-		1.60	
	5	-		0.20		1.70		1.70	
	6	-		-		-		1.60	
	Ave.	1.33		0.25		1.67		1.73	

Note: Some figures of transparency in case of overflow through the Anti-Turbidity Overflow System are greater than those before the overflow. This is considered to be due to a slight difference in sampling spot of sea water.

OOZER PUMP DREDGE

According to a paper by Mr. Kasuyoshi Nishi (see references) the Toyo Construction Company has developed an Oozer Pump dredge that is characterized by the same ease of operation as ordinary suction pump dredges without secondary contamination problems. A sketch and photograph thereof follow:

Operation of Oozer Pump Dredge


Ball valve at discharge outlet
Release of air & creation of vacuum
Upper level detector
Lower level detector
Vacuum
Conical at suction inlet
Water pressure
(Suction process)
Movement
Sludge discharge
Intake of air & delivery of compressed air
(Discharge process)

The TAIAN MARU, one of Toyo Construction's Oozer Pump Dredges

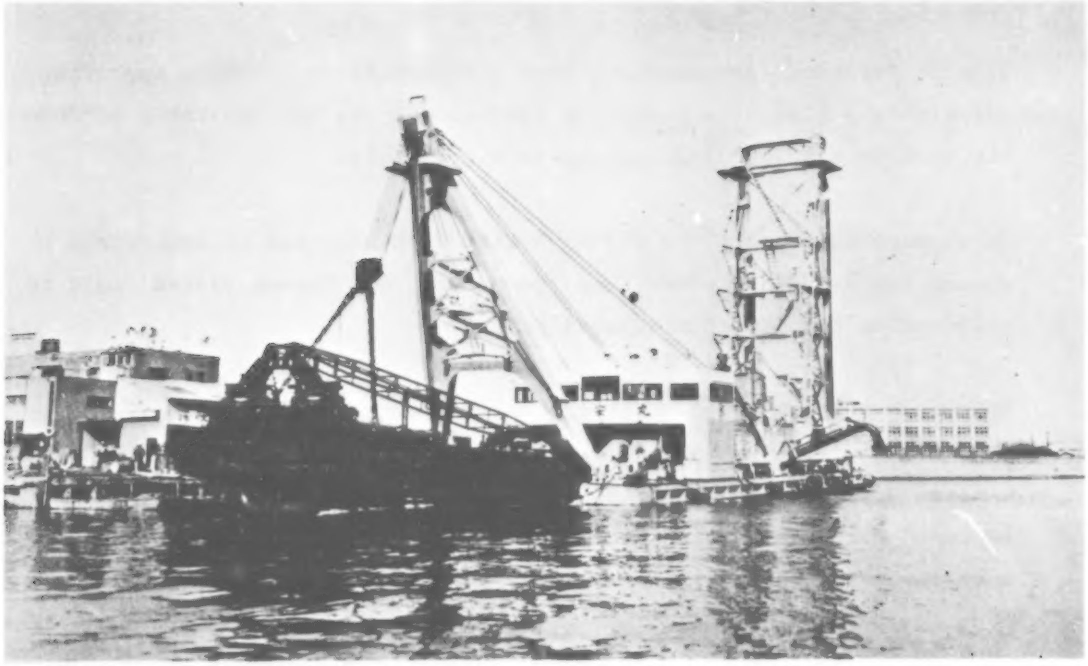


Figure A-22. Oozer Pump Dredge

(Nishi, Courtesy of WODCON VII)

Operation of the Oozer Pump dredge is as follows:

a. Suction process. As a vacuum plus water pressure is created inside the tank, the sludge pushes up the conical suction valve and flows into the tank. The vacuum pump is not needed when the operation is carried out at a depth where water pressure alone is sufficient. When sludge has risen to the level of the upper sensor rod, the sludge suction cycle terminates.

b. Discharge process. Compressed air is delivered into the tank by the compressor. This pressure in the tank causes sludge to push up the ball valve at the outlet and to be discharged until the level reaches the tip of the lower level sensor rod.

c. Pressure releasing process. Upon completion of the above-mentioned suction and discharge processes, residual pressure inside the tank is released into the air. Then the operation is repeated.

Usually two tanks are used as front attachments to increase operating efficiency. Sludge is pumped up continuously as the two tanks perform the suction and discharge processes alternately.

In essence the Oozer is a Pneuma system with only two cylinders and a vacuum for dredging in very shallow water. The Pneuma system could be modified to provide this capability.

The Oozer Pump has been installed on the company pump dredge, TAIAN MARU. The dredge has a length, width, and depth of 37.9 X 12 X 3 meters, respectively (the depth is about 10 feet.) The pump is equipped near the suction attachments with a sonar device, which actually measures the thickness of sludge deposited on the seabed, and an ultrasensitive underwater television camera which monitors secondary water contamination. The craft is equipped with two spuds for precise control of its swinging motion so that no sludge remains after dredging is completed.

Mr. Nishi states that the Toyo Construction Company has drawn up a plan prior to each dredging operation to determine the extent of the effects on water quality. A set of data collected by the company for one dredging project is given in the following table. It indicates that there was no secondary dispersion of sludge in seawater. Points where samples were taken are also shown. The company used a transmissometer, MARTEK'S Model XMS 1/2 developed in the U.S.A. and especially designed for optimum underwater measurements of turbidity.

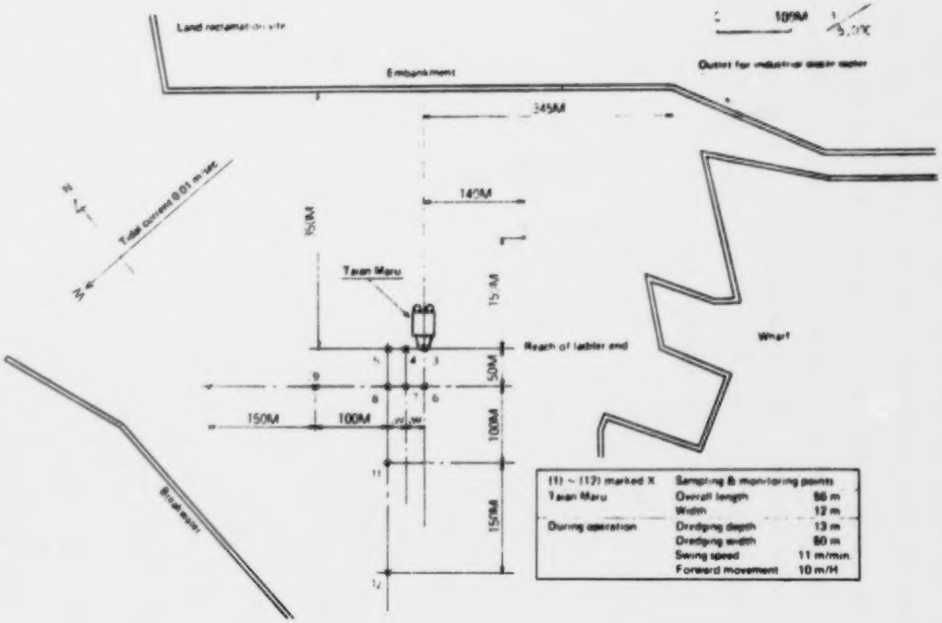

Land reclamation site
Embankment
100M
1/5,000
Outlet for industrial waste water
345M
140M
Tidal current 0.01 m/sec
N
W
150M
Taian Maru
150M
Reach of ladder end
Wharf
1
2
3
4
5
6
7
8
9
10
11
12
50M
100M
150M
100M
150M
Breakwater
(1) ~ (12) marked X
Sampling & monitoring points
Taian Maru
Overall length
56 m
Width
12 m
During operation
Dredging depth
13 m
Dredging width
80 m
Swing speed
11 m/min
Forward movement
10 m/H

Figure A-23. Changes in Water Quality (Investigation Results) Using Oozer Pump Dredge

(Nishi, Courtesy of WODCON VII)

Table A-12. CHANGES IN WATER QUALITY (INVESTIGATION RESULTS) USING OOZER PUMP DREDGE (Nishi, Courtesy of WODCON VII)

Date of investigation: July 5, 1974 Weather: mostly cloudy

Item / Points (In order of sampling)	Before operation					During operation (1st time)					During operation (2nd time)		
	Data obtained					Data obtained					Data obtained		
	SS		Turbidity		Trans-parency	SS		Turbidity		Trans-parency	SS		Trans-parency
	0.5 m BWL	10 m BWL	0.5 m BWL	10 m BWL		0.5 m BWL	10 m BWL	0.5 m BWL	10 m BWL		0.5 m BWL	10 m BWL	
1	16		7		60 cm	21		8		60 cm	30		40 cm
2						6		2		1.20	11		95
3	15	2	6	< 1	1.80	4	< 1	1	< 1	2.00	17	2	1.50
4	5	4	1	< 1	1.00	3	2	< 1	< 1	1.60	3	2	1.40
5	6	3	2	< 1	1.20	3	2	1	< 1	1.00	8	2	90
6	3	1	1	< 1	1.10	2	2	< 1	< 1	1.80	6	2	1.20
7	5	2	2	< 1	1.20	6	3	4	1	1.90	6	2	95
8	3	4	< 1	< 1	1.30	6	2	1	< 1	1.70	2	2	1.50
9	6	2	3	< 1	1.60	8	2	5	< 1	1.50	7	2	1.10
10	2	2	< 1	< 1	1.60	2	2	< 1	< 1	1.60	3	2	1.40
11	3	2	1	< 1	1.90	4	2	1	< 1	1.30	3	2	1.40
12	3	3	< 1	< 1	1.40	4	2	2	< 1	1.20	3	2	1.25
Sampling & test time	11:00 ~ 12:05					12:50 ~ 13:55					14:00 ~ 14:55		

Notes: Points where samples were taken shown in previous figure.

Sampling method: Suspended solids (SS) and samples for turbidity tests were taken at 0.5 and 10 meters below the water surface using water samplers.

Test methods: Procedures specified in JIS K0102 10.2.1 were applied to the testing of suspended solids. Turbidity was measured by the photoelectric photometric method specified in JIS K0101 8.2. Water transparency was measured in accordance with oceanological observation standards of the Japan Meteorological Observatory.

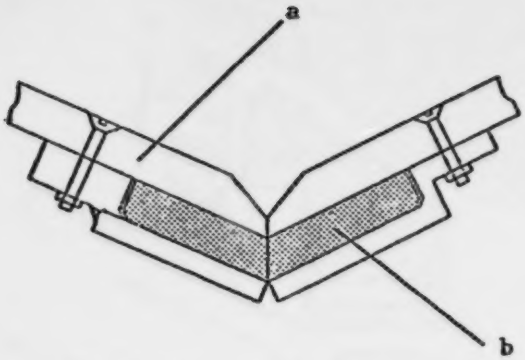
WATERTIGHT GRAB BUCKET

Other than dredges of the pump type, the grab type dredges have been partially utilized in Japan in the removal of sediments. The grab bucket is capable of collecting the sediments; however, the defects in this method are the large quantity of turbidity generated and the low accuracy of the collection. To correct these defects, a modified watertight grab bucket has been developed.

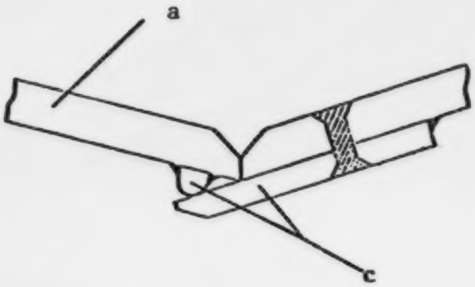
The Mitsubishi Seiko Co., Ltd., in collaboration with the Association of the Bay and Harbor Consultants of Japan, has developed a special bucket for dredging settled sludge. According to the company, the bucket is of the closed type, especially designed for dredging without giving rise to secondary pollution when it is used for dredging settled sludge. The amount of turbidity generated is 30-60 percent less than that generated by the typical open bucket. There is still resuspension of material created as the bucket impacts the bottom, is pulled off the bottom, and is pulled up through the water column.

There are two designs of buckets--the link and lateral types. The link type can be used in sites where spoiling and turbidity must be prevented when dredging channels and harbors. The lateral type can be used in ground digging wherein a smoothly dredged surface is particularly required in addition to the prevention of spoiling and turbidity.

According to the company, the bucket is watertight if material and debris are not caught in the jaws. The mechanism consists of an upper cover and a double plane contact at the bottom of the bucket--one contact of which is hard rubber. It can be attached directly to any conventional grab dredge. Photographs of typical buckets follow.



Hard Rubber Technique



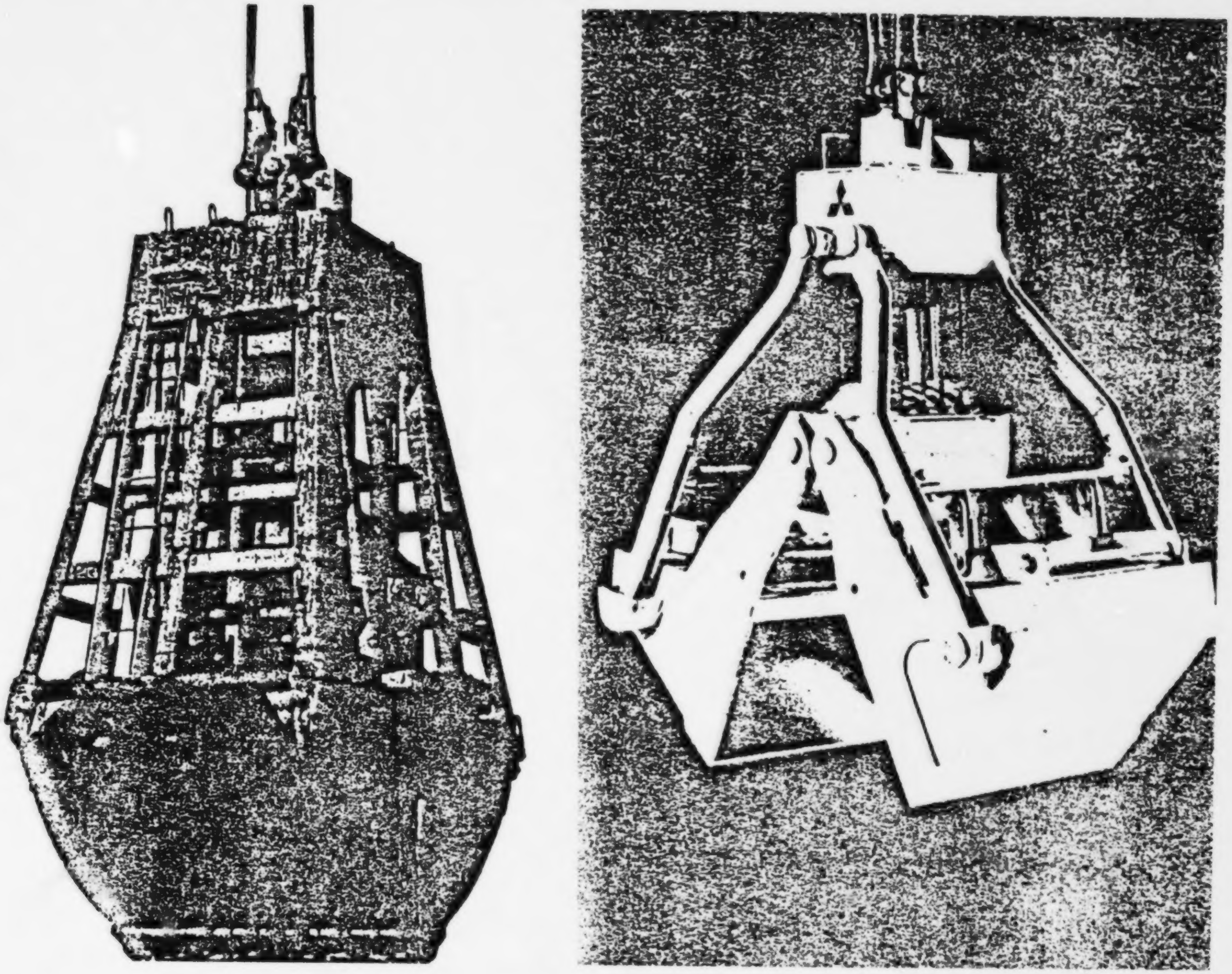
Two-plane Contact Method

Legend

a. Shell Edge
b. Hard Rubber
c. Plate

Figure A-24. Methods of Sealing Watertight Grab Bucket

(Mitsubishi Sako Co., Ltd.)



Link Type Water-Tight Bucket

Lateral Dredging Type Water-Tight Bucket

Figure 25. Watertight Grab Bucket (Mitsubishi Sako Co., Ltd.)

SUMMARY OF DREDGING ACTIVITIES IN JAPAN

In a paper by Messrs. Koba, Shinohara and Sato, (see references), it is stated that the technique for judging amongst the various dredging technologies and the necessity for dredging based on the status of the sediment, as well as the various environmental conditions surrounding it, is still extremely primitive. Actually the dredging technology for removing polluted sediments has only developed recently and in only a few actual examples in Japan.

Their paper states that in sediments containing a large amount of mercury and PCB (polychlorinated biphenyls) in pulp wastes, it is necessary to prevent the diffusion of the suspended particles during dredging operations and to collect them as much as possible. Thus the major problem of sediment dredging is the prevention of the generation of secondary pollution caused by dredging. Accordingly, it is necessary to develop suction devices which are absolutely capable of collecting and removing sediments without increasing turbidity.

They refer to the Clean Up dredge with its moveable wing which covers the surface of the sludge to be dredged, the built in auger, and the fact that the contacting pressure and posture of the equipment can at all times be maintained against the sediments. They also refer to the Pneuma pump which moves sediments under air pressure and that is well suited for removal of viscous sediments. Both the Pneuma and Oozer pumps are being used, the Oozer pump being a modification of the Pneuma. The excellent capability of the Oozer pump has been confirmed and the generation of turbidity is small.

Other than the dredge of the pump type, the grab type dredge has partially been utilized in the dredging of sediments. The grab dredge is capable of collecting the sediments close to the actual sediments on the bottom, but the defects of this method are the large quantity of turbidity generated and the low accuracy of the collection. To correct these defects, the modified grab bucket has been developed.

Problems associated with the transportation of sediments are the necessity to prevent leakage and to deodorize and eliminate gas. Barges and/or pipelines must be tight. In pipe transportation, the movement of the viscous fluid and the resulting viscous drag must be studied, and the pipe size and power required carefully planned.

Development of better monitoring systems are needed to comprehend precisely if the total system is in operation within the regulatory system limits set forth for the environment. Future problems for resolution include:

- Research and development of methods to stabilize and change toxic substances as they are contained in the sediments to a harmless matter.

- Development of a method to positively recover the natural purification capacity of the seabed after dredging and the evaluation of its effects.

DREDGING TECHNOLOGY IN ASIA, AFRICA, AUSTRALIA, AND SOUTH AMERICA

There are many dredges of all types located in Asia, Africa, Australia, and South America. As far as can be ascertained, dredging is generally performed with the major equipment manufactured in the United States, Europe, and Japan. For example Russia has recently received the largest ship in its dredging fleet that was constructed in Holland. It is a heavy-duty, trailing, suction hopper dredge. The Republic of Zaire recently acquired two trailing, suction hopper dredges from Holland companies. Electronic systems and mechanical components, required as a part of the dredging equipment, are, in some instances, manufactured in the countries concerned. The equipment is modified as necessary to fit the conditions existing in these other continents.

METHODS UTILIZED TO AVOID RESUSPENSION OF SEDIMENTS

There are very few examples in this country wherein dredging of noxious materials was accomplished concurrently with an attempt to avoid or reduce resuspension of sediments. Studies are now underway to remove PCBs from the Hudson River, Mirex from Oswego River, New York, and PCBs in Waukegan Harbor in Lake Michigan.

Details of two examples of actual accomplishments are presented in the following paragraphs. They are:

a. The Port of Tagonoura, Japan, and

b. The Duwamish Waterway in Seattle Harbor, Washington.

PORT OF TAGONOURA, JAPAN

The Port of Tagonoura (see references) is located at the confluence of four streams--Urui, Numa, Wada, and Fuji Rivers. The port has been in existence since 1670 and its area had been famous for Mount Fuji which was reflected in the water since ancient times.

Utilization of the clean waters at the foot of Mount Fuji had brought prosperity to 155 paper manufacturers in the area. In 1970, they disposed of 2.5 million tons of sewage per day containing 980 tons of suspended solids in a dry state into the port. Suspended solids, totaling 300 tons, became 3,000 tons of bottom sediments containing 90 percent water. The sediments consisted mainly of fibers in the paper factory sewage, contamination from the food factories, or domestic sewage and the coagulation of the fibers in an environment fit for their existence--namely anaerobic bacteria that can exist in salt or half saltwater without dissolved oxygen. The following tables highlight the contamination problem that existed.

Table A-13. COMPONENTS OF SEDIMENT, TAGONOURA

Component	Percent
Water 1/	85 to 90
Fiber	7 to 11
Salinity	3
Earth and sand	1
Sulfide	0.035 (free sulphur = 60% to 70%)

1/ Percent of water shown as water content or percent of total weight in the above components.

Table A-14. Hg AND Ca CONTENT, TAGONOURA

	Parts per million	
Item	Hg	Ca
Sediments (90% water)	0.131	0.330
Water in the port	0.003	0.001

Table A-15. COMPONENT OF GAS, TAGONOURA

Gas	Percent
Methane	61.00
N	33.00
CO_2	1.70
H_2S	0.20
CO	0.01
O	3.90
Other gases	0.19

In the past, the sewage and sediments were dredged and deposited into the sea. In 1970, ocean disposal of the sediments was stopped due to complaints by fishermen. Consequently, the volume of sediments on the port bottom increased rapidly and eventually a portion of the port bottom was exposed during low water. During the summer, the toxic and foul-smelling gases injured the environment of the port. Also, with the decrease in depth of water in and around the port, the sedimentation capacity available for suspended solids decreased; thus, the volume of suspended solids flowing to the sea increased. During the typhoon season, there was a danger that toxic sediments might be washed into water outside the port, thereby contaminating marine life.

This condition was reported by television and the press all over Japan for some time and was considered sufficiently serious as to warrant discussion in the National Diet. Pollution in the Port of Tagonoura became an important topic in Japan. Furthermore, the solution to this problem, the proper removal of a large quantity of toxic bottom sediments, was one of the first such cases in Japan. Thus there was no guidance from a similar study.

At first it was planned to remove the sediments by suction dredge, to carry them in a self-propelling barge to the open sea 320 kilometers from the Port of Tagonoura, and dump them there. However, ocean disposal of the sediments containing toxic substances in large quantities might contaminate the sea. Furthermore, popular opinion had started a movement against this plan, and scientists attending a world oceanography congress also opposed it. Therefore this plan was abandoned.

Since the sediments contained about 90 percent water, they had to be dehydrated. Furthermore the foul odors, toxic gases during sediment dehydrating, and contamination of ground water caused by the infiltration of contaminated water after dehydrating had to be avoided. It was also necessary to insure that the living environment was not contaminated after the relocation of the dehydrated sediments.

Therefore extensive space was needed far from a residential area. The dry riverbed of the Fuji River, about 5,000 meters (16,000 feet) from the port, included an area far from human habitation. Gravels and cobble stones to serve as a filter layer for the water were available there. Accordingly, a large dehydration pond was planned on this dry riverbed.

The plan developed generally included the following:

a. Bottom sediments were removed by a cutterless suction dredge into a self-propelling barge. When filled, the barge was moved to a mooring dock where a pipe connected to land. Where a barge was not used, the dredge connected directly to a land pipe.

b. A land booster pump moved the sediment and water through the pipe to a dehydration pond. Chemicals were added during the operation, thereby providing protection to workers and to the environment during dredging and dehydration.

c. Material removed from the dehydration pond was placed either in the dry riverbed or on land adjacent to port facilities. Water released from the dehydration pond flowed to the Fuji River.

The sediments were dredged and then mixed with a solution of slaked lime, $Ca(OH)_2$, for removal and/or reduction of hydrogen sulphide gas. Next $FeCl_3$ and a cohesion agent were added to the slurry (sediment and water) as flocculants. Then the slurry was discharged into the dehydrating pond. By this time, the slurry had flocculated. Here the clear water in the upper portion of the sediments flowed successively from one pond to the next. Eventually it was discharged into the ground near the mouth of the Fuji River. A sketch showing treatment activities is shown on the following page.

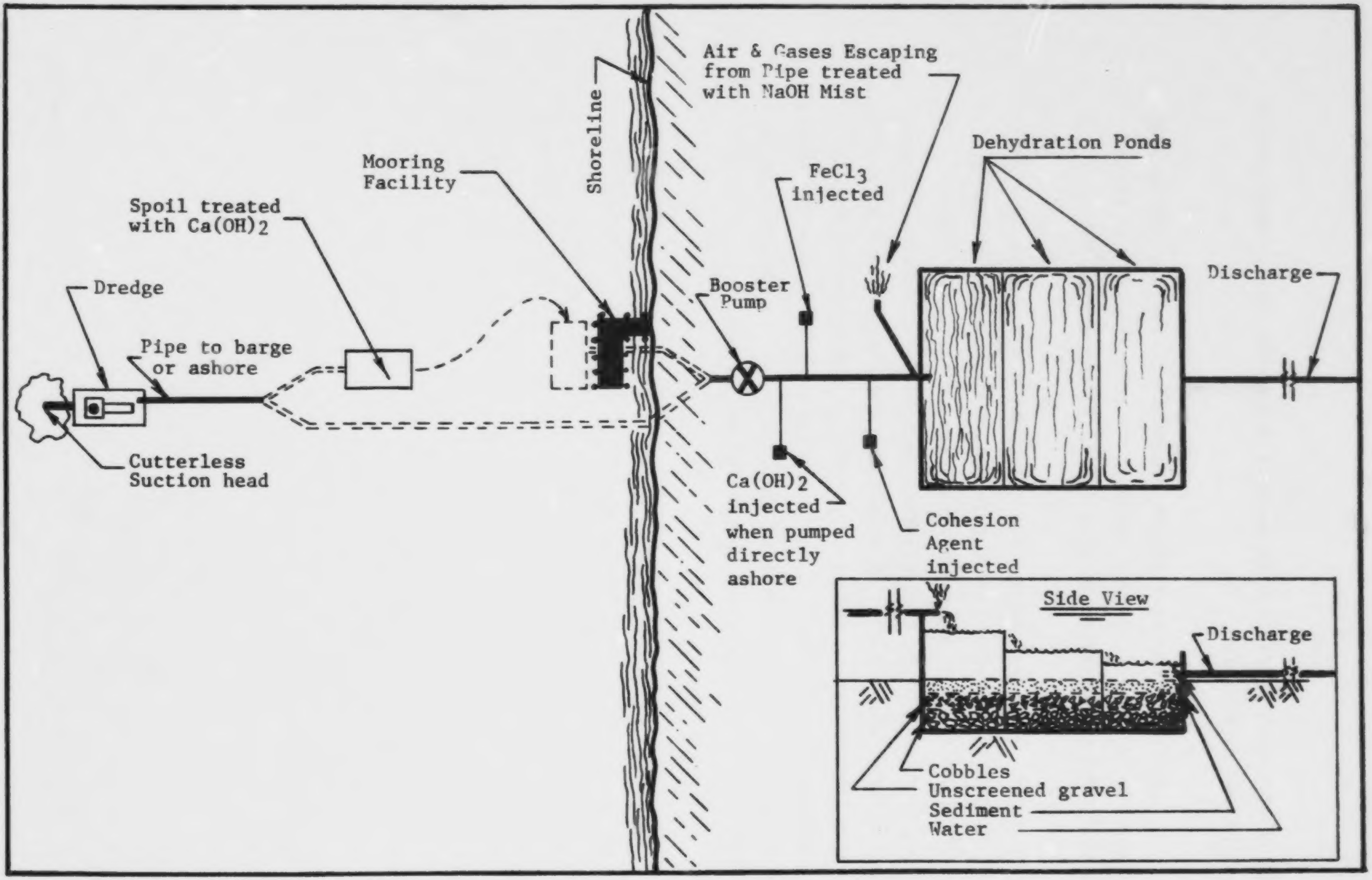

Air & Gases Escaping from Pipe treated with NaOH Mist
Dehydration Ponds
Mooring Facility
Shoreline
FeCl3 injected
Spoil treated with Ca(OH)2
Dredge
Booster Pump
Discharge
Pipe to barge or ashore
Cutterless Suction head
Ca(OH)2 injected when pumped directly ashore
Cohesion Agent injected
Side View
Discharge
Cobbles
Unscreened gravel
Sediment
Water

Figure A-26. Taganoura. Treatment of Contaminated Sludge

(Based on data by Masao Sato)

After about 2 weeks, the sediments with a water content of 75 to 80 percent were carried by truck from the dehydration ponds and mixed with the gravel and cobble stones of the dry riverbed in the ratio of one to one. On this reclaimed land, a sporting square covering an area of 100,000 square meters (25 acres) is now used by the citizens each day.

Checks in the vicinity of the reclaimed ground were made with pipe wells to determine the limit of PCBs and whether the temperature rose and fell with the atmospheric temperature to insure that abnormal fermentation was not occurring in the reclaimed ground. Other types of checks were made to determine the extent of H_2S gas in the dehydration ponds, in the dry riverbed near the reclaimed ground, in areas inhabited near the riverbed, at the mouth of the Fuji River, and in the port area. Abnormal conditions were not found, but if measurements had exceeded a fixed value, all work would have been stopped. Checks were also made of the amount of PCBs in young yellowtail mackerel, sardines, and other fish in Suruga Bay. In April 1972, use of noncarbon toilet tissue was prohibited. Because of this and the removal of a large quantity of sediments, PCB in the Port of Tagonoura was decreasing.

It is interesting to note that members of the local and regional governments had to visit the inhabitants and fishermen near the port many times, and considerable time was necessary to obtain their consent to the plans and to the location of the disposal area. They opposed the works that might injure the land environment with H_2S gas and PCB. During the dredging operation, a pipe carrying the sediments burst and the slurry flowed over a hamlet and work had to be suspended for several months. As the work had been done in a disordered condition, some of the investigations and observations could not be done systematically. The records, therefore, are not orderly.

DUWAMISH WATERWAY, UNITED STATES

An electrical transformer containing PCB was dropped during barge loading operations on 13 September 1974. As a result, 260 gallons of PCBs were spilled into slip 1 of the Duwamish Waterway, Seattle Harbor, Washington. Location of the spill was approximately 3 miles upstream from where the Duwamish Waterway enters Elliott Bay (Puget Sound).

An emergency removal operation was undertaken by EPA in which divers utilizing small hand-held suction dredges pumped the water, PCBs, and contaminated bottom sediments into settling tanks. Even though 70 to 90 gallons of the PCB were removed during this operation, sampling of the remaining sediments indicated that large quantities of bottom sediments were contaminated and an enlarged dredging and disposal operation would be required. The U.S. Army Materiel Command was assessed liability for the accident due to faulty packaging of the transformer. On 24 September 1975, over 1 year after the spill occurred, the Seattle District, Corps of Engineers was tasked with responsibility for removing the remaining contaminated materials.

During the preceding year, periodic sampling had been accomplished by regional EPA personnel. Indications were that the spilled chemical was being distributed throughout the slip, with some migration to the adjacent waterway. EPA estimated that 2 feet of contaminated material would have to be removed across the entire slip, with deeper dredging at the point of spill. This would encompass removal of 27,000 cubic yards from the slip and 20,000 additional cubic yards from the adjacent waterway. However, flooding during December of 1975 diluted or dissipated the material in the waterway to the extent that its removal was no longer required.

The plan originally developed was to pump the contaminated materials into large barges, tow the barges to a disposal site, and then pump the contaminated material into an excavated pit near the shore. Numerous disposal sites were investigated. Almost everyone contacted indicated great reluctance to consider acceptance of the contaminated materials. Many disposal site owners indicated a desire to have a "hold free of damages" clause in the lease agreement. Only by congressional action could such a provision be included. On 11 February 1976, agreement was reached to use a sewage treatment plant that had been abandoned by the city of Seattle. It was privately owned and located 2,400 feet south of the spill site.

Two 25,000 cubic yard pits were excavated in the existing sludge bed areas. The material excavated was utilized for construction of dikes around the pits. A cross-dike was left between Pit #1 and Pit #2 to create better ponding and settling of the dredged materials. A dredge spill box structure allowed decanted water to flow from Pond #1 to Pond #2. The large pit volume relative to the low dishcarge rates reduced cross-section flow velocity in the disposal areas to less than 1 foot/hour. Construction of the pits started on 14 February, and excavation was completed on 28 February 1976.

A sketch and photographs of the operation follow. Dredging was accomplished with a 600/100 size Pneuma pump with three scoops. The Pneuma system was utilized because of its ability to pump high concentrations of solids and dredge with very minimal increases in bottom turbulence or turbidity. High solid concentrations were required to reduce the total water volume, which would require filter treatment. The dredge arrived in three truck trailer loads on 23-25 February 1976. Two persons from Pneuma North America were contracted to supervise the pump's operations. The Pneuma pump was suspended from a crane working from a self-propelled barge. Three compressors and the distributor system for each scoop were also mounted on the self-propelled barge. The starboard (right) side of this self-propelled barge was attached to another barge equipped with two spuds. One spud was used as a pivot/anchor for both barges, while the propelled barge supplied the power to swing both barges and the Pneuma pump in a wide arc over the bottom. After the cut had been made the pump was raised off the bottom, the self-propelled barge was swung back across the same arc, the spud barge stepped ahead, and another circular cut was made. There were no swing wires used in this particular operation. The water depth was 30 feet.

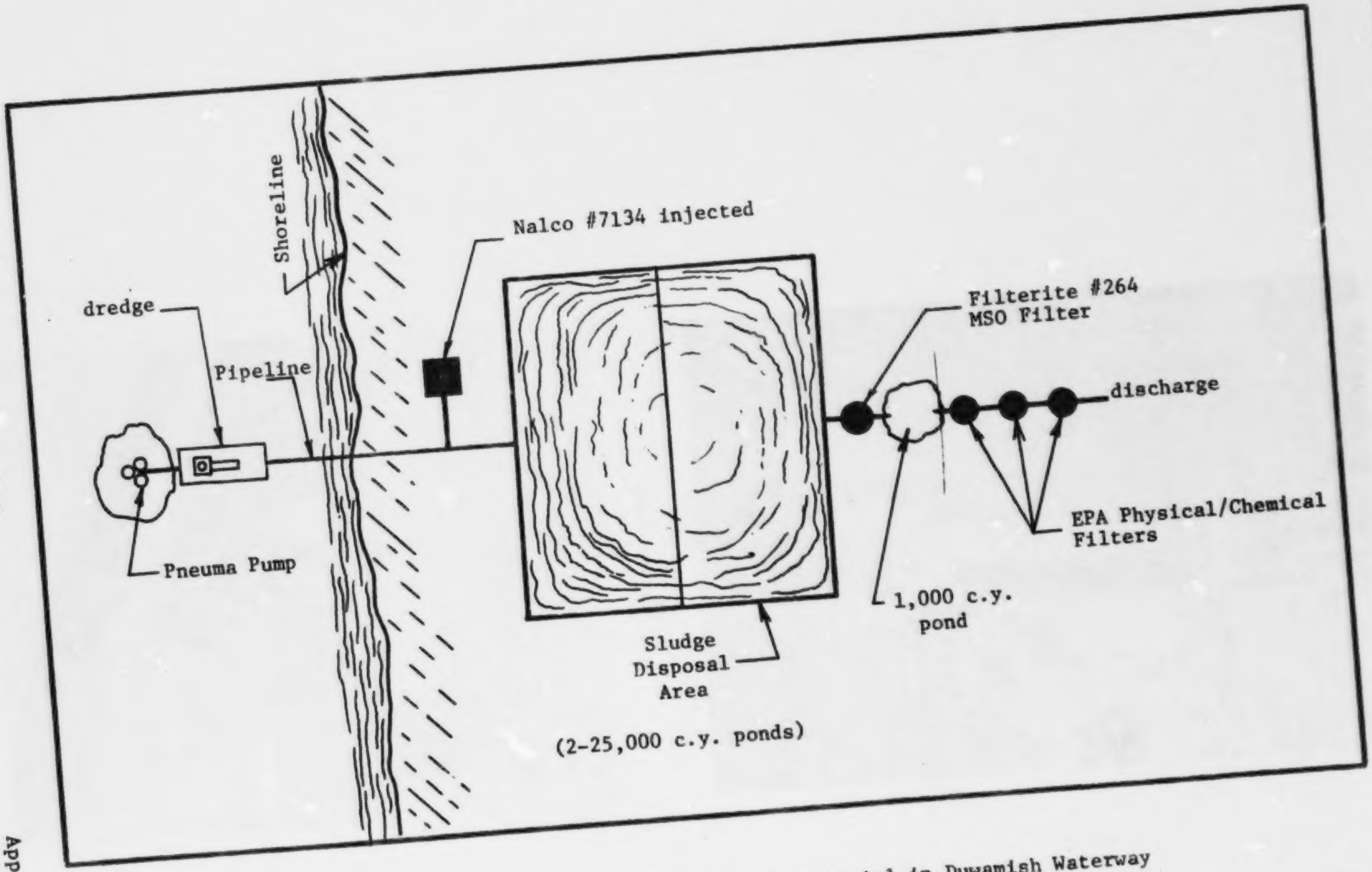
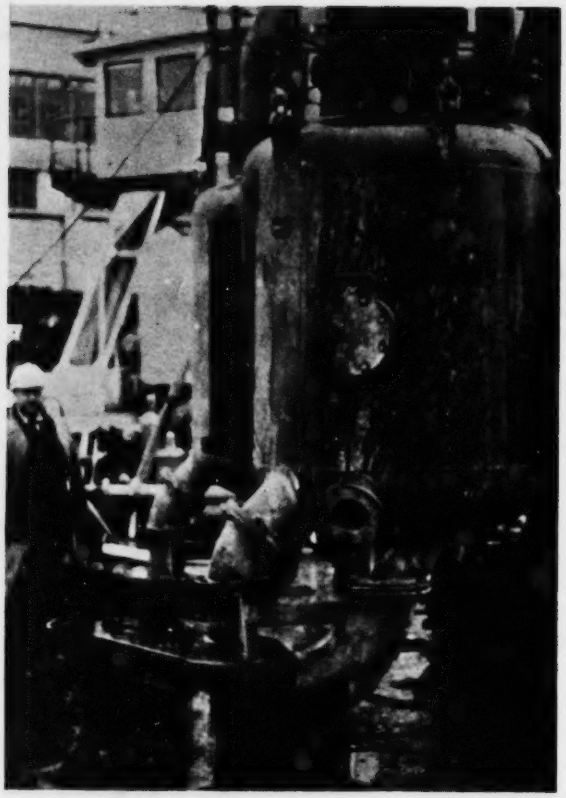
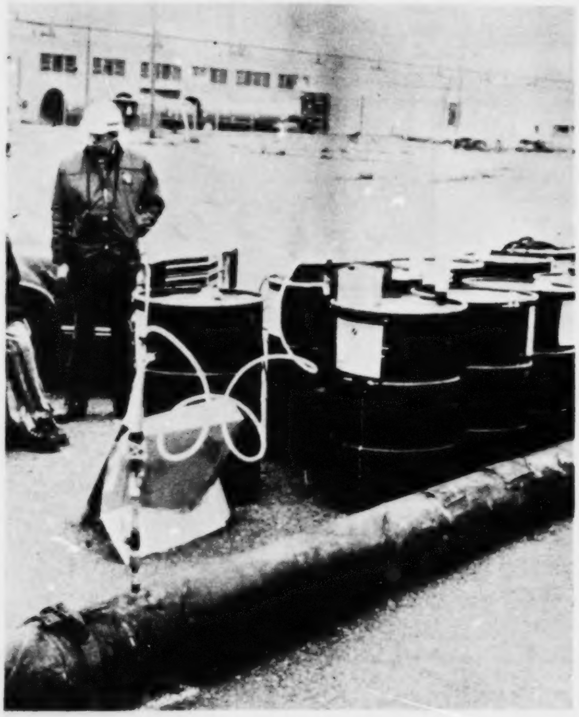

Shoreline
Nalco #7134 injected
dredge
Pipeline
Pneuma Pump
Sludge
Disposal
Area
(2-25,000 c.y. ponds)
Filterite #264
MSO Filter
discharge
EPA Physical/Chemical
Filters
1,000 c.y.
pond

Figure A-27. Treatment of Contaminated Material in Duwamish Waterway

(Seattle District, Corps of Engineers)

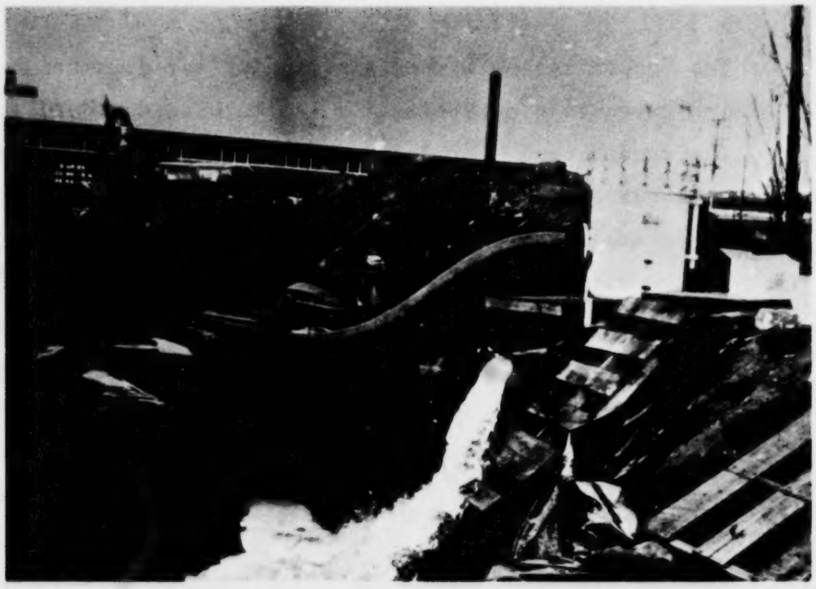


Pneuma Pump

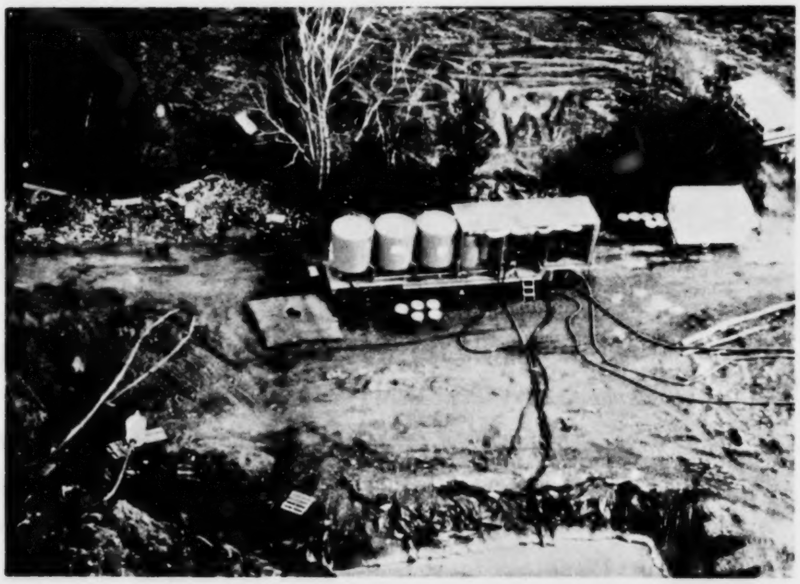


Injection of Nalco 7134

Figure A-28. Operation, Duwamish Waterway (Seattle District, Corps of Engineers)



Filterite #264 MSO Filter



E.P.A. Physical/Chemical Filter

Figure A-29. Operation, Duwamish Waterway

(Seattle District, Corps of Engineers)

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The Pneuma system worked satisfactorily; downstream monitoring indicated that exceptionally low turbidity did exist in the vicinity of the dredge pump. Dredging areas filled with trash will greatly increase the dredging time, since about 4 hours is required to disassemble and clean valves should they be plugged by trash. In fluid or low viscosity materials, relatively high concentration of solids can be obtained. The dredging time was 81 hours or 36 percent of the working hours. The low effective time was due mainly to personnel on the boat who were not familiar with dredging operations. Approximately 3 days were lost due to various mechanical repairs to the dredge and associated equipment. The dredged material slurry was pumped through about one-half mile of 10-inch pipeline at a rate of about 3,000 gallons per minute into the containment area which was 8 to 10 feet above the elevation of the Duwamish River. No booster pump was necessary.

About 300 feet from the discharge point, the dredged material slurry was treated with Nalco 7134 (a low molecular weight, cationic polymer) at a rate of 20 parts per million to increase the settle- ability of the dredged material in the disposal area. This flocculant appeared to be very effective.

The dredged material was discharged into the first pond at a rate of 3,000 gallons per minute (for about 5 hours); then the overflow passed into the second pond where the surface water was pumped out of the pond and through a 2,000 gpm Filterate filter for 8 hours per day. This insured that all particles coarser than 50 microns were removed and the filtrate placed in a small (1,000 cubic yard) holding pond. The effluent in the holding pond was then pumped through three large activated charcoal filters supplied by EPA, which were arranged "parallel" to produce a combined filter capacity of about 600 gpm. After the effluent had been processed through the charcoal filter, it was discharged into the Duwamish River. Testing by EPA indicated that PCB concentrations were as follows:

a. 8 to 10 parts/million in sludge being pumped into the disposal pit,

b. 4 parts/billion in decanted water, and

c. 50 parts/trillion in water returned to Duwamish River.

This was an important operation in that it was:

- The first time the Corps of Engineers had utilized the Pneuma pump,
- The first major dredging operation undertaken in the United States to remove PCBs, and
- The first time effluent filtering had been utilized in conjunction with dredging operations.

RESULTS OF ON-SITE SURVEY OF JAPANESE DREDGING TECHNOLOGY

An evaluation of the dredging technology on the world market revealed two promising approaches to clean up Bailey Bay and surrounding areas. These two approaches are the Japanese developed Oozer dredge and the dredge spoil fixation process (described in later paragraphs). Therefore, during the period from 4 to 17 March 1978, representatives from the Environmental Protection Agency and the Corps of Engineers visited Japan for an on-site evaluation of both the Oozer dredge and the spoil fixation process. The Oozer dredge was designed and developed by the Toyo Construction Company while the spoil fixation process was developed by Takenaka Komuten Company, Ltd.

In Japan, the sediment that accumulates in streams and the sea consists of very fine particles with an extremely high water content. The resulting sludge is extremely soft. It is generally dark and cohesive and the natural water content is normally about 150 to 200 percent, but on the sea bottom, there are cases where it reaches as high as 400 to 700 percent. It invaribly liquefies when agitated. Grain size distribution includes silt and clay, while sand comprises from 3 to 30 percent.

Harmful substances such as cyanogen, cadmium, lead, chromium, arsenic, mercury, and polychlorinated biphenyl (PCB) contained in wastes discharged from various types of factories are now found in the sludge in increasing amounts. Some of these find their way into fish and shellfish which are consumed by humans, thereby causing health hazards. There are also innumerable cases wherein offensive odors are emitted from deposited sludge to adversely affect the environment of people in the vicinity. Lastly, the functions of ports, harbors, and waterways are greatly hindered by deposited sludge. Port Tagonoura is an example of a seaport which almost lost its serviceability due to deposition of waste pulp liquors discharged from paper mills.

THE OOZER DREDGE

Toyo Construction Company has developed two sizes of Oozer dredges (patents are pending in the United States):

Large Oozer (TAIAN MARU)
Small Oozer

TAIAN MARU - Physical Description. In January 1974, the company developed an Oozer dredge, the TAIAN MARU. The hull has a length, width, and depth of 37, 10, and 3 meters, respectively. It is a swing type dredge equipped with two spuds and winches for precise control of its swinging motion so that little sludge is left after dredging. The swing speed is adjustable in a range of 0 to 20 meters per minute and dredging can be accomplished without producing significant secondary pollution even in the case of easily agitated sludge. It is capable of dredging to a depth of 18 meters.

The Oozer itself is quite large and includes a cylindrical twin barrel with a vacuum pump on the dredge to provide negative pressure and an air compressor to provide positive pressure discharge. The two cylinders are connected into a single pipe leading to the suction mouth. A metal hood over the suction mouth is 20 feet long and 6 feet wide and is similar to the hood over an oven. It will recover oil or gas contained in the sediments and thereby prevent contamination of the sea. Below this hood there is another cover over the suction mouth to prevent turbidity and/or secondary pollution. Special cutters have been designed for relatively hard soils. For example where clayey and/or sandy soils are to be dredged, a special suction head with cutters--the equivalent of a clamshell--is lowered by the winches. This has teeth which cut into the material to be dredged. The loosened material is then forced up into the suction inlet by the hydrostatic pressure and vacuum created in the Oozer.

The control room is similar to a control room on a conventional type dredge, but it includes additional equipment to prevent secondary pollution. A television screen monitors the extent of secondary contamination created by the dredge. It is attached to two sensitive underwater television cameras equipped with power-driven zoom lens which are installed at the suction mouth of the Oozer to monitor the turbidity of the water. A video tape system available to record the amount of pollution. Another instrument on board is a turbidimeter which quickly detects and records any secondary contamination. A sediment detector measures the thickness of the sediment layer to be removed. It is based on five sludge probes provided around the suction inlet. This detector indicates numerical valves on an analog computer. The first graph shows the top of the cut and the second panel shows the depth of cut. Residual air to be released into the atmosphere during operation of the Oozer Pump is first led into a muffler, after which it is filtered to meet air quality standards. According to the company, since the Oozer uses a vacuum pump in addition to water pressure for the forcible suction of sludge, a high concentration of the material is dredged in its existing form without agitation as a result of removal and without causing turbidity. Futhermore, since a vacuum pump is used, dredging is not affected by depth and even sludge in shallow water can be removed.

Other instruments on the vessel are a flow-direction flow velocity meter, a simplified gas detection meter, a sludge sampler, a water sampler, and a transparency meter. Photographs and a graphical representation of the TAIAN MARU follow.

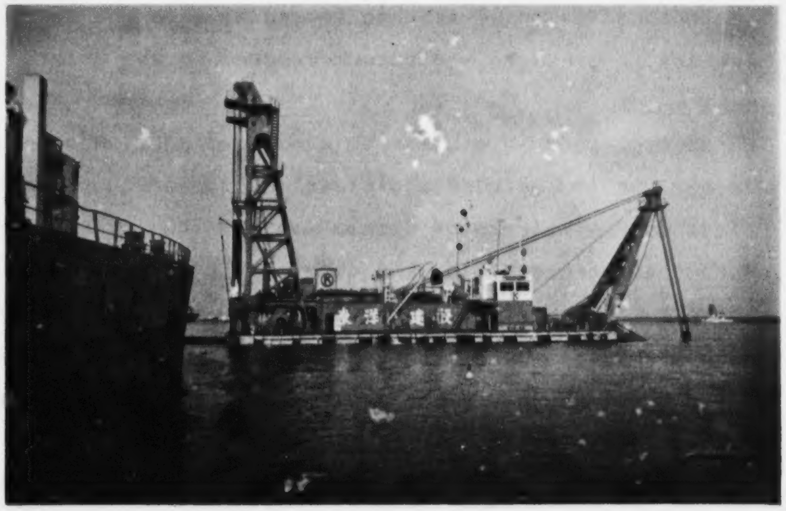
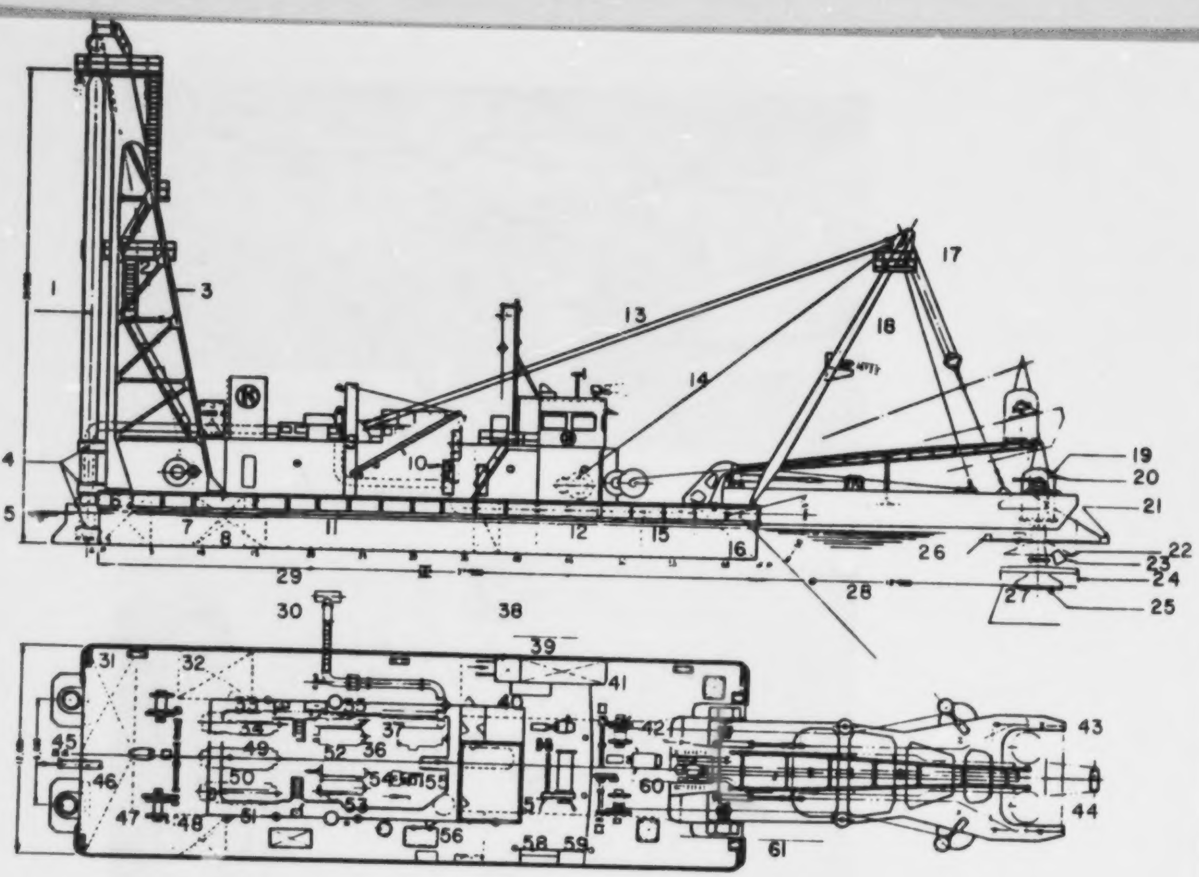
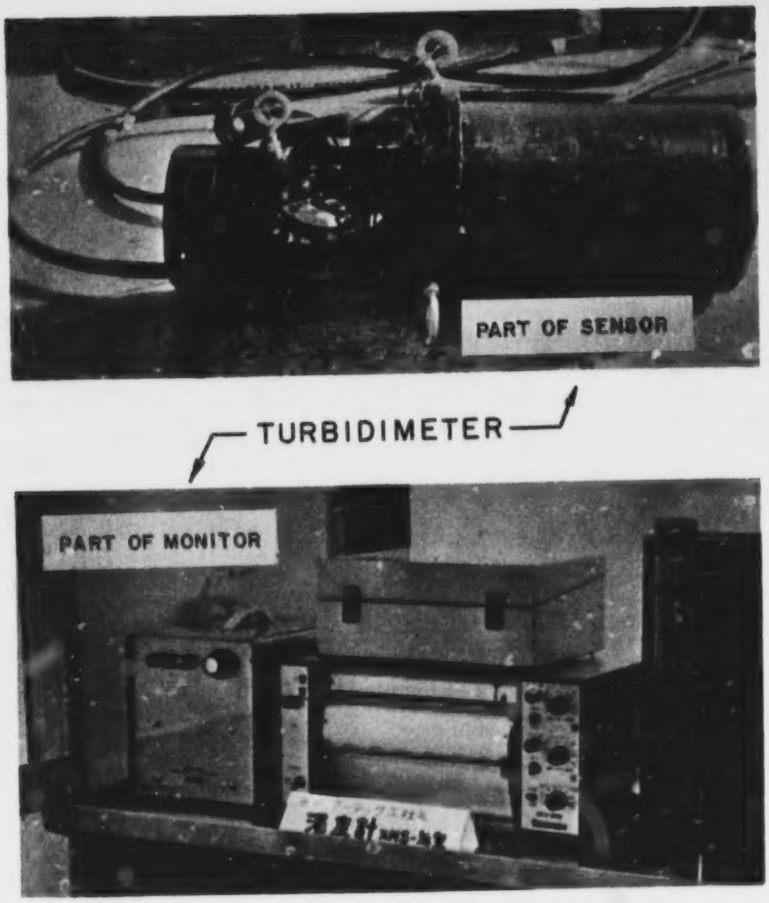


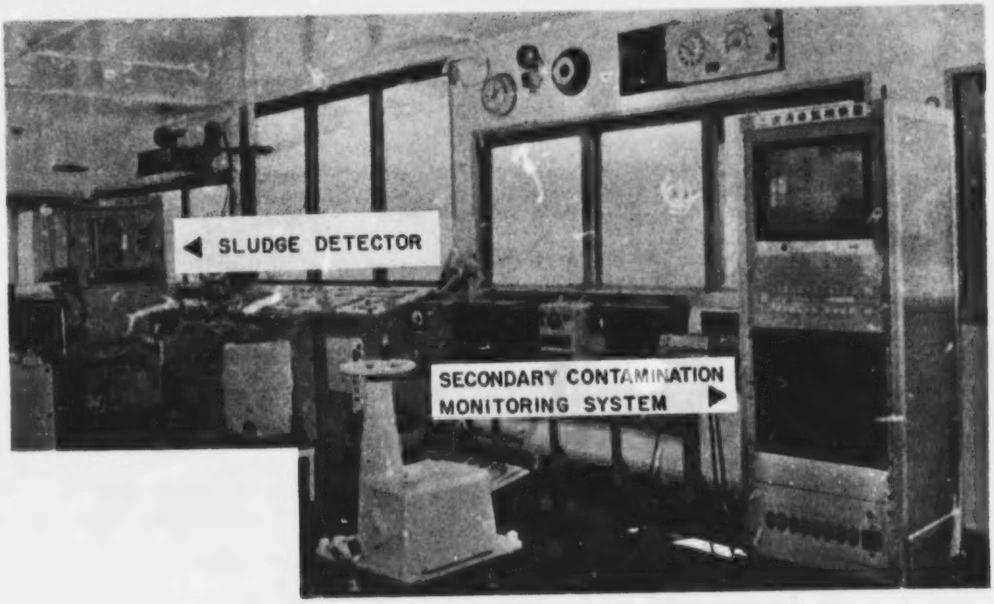
Figure A-30. TAIAN MARU Dredge



1. Spud
2. Spud hoisting cable
3. Spud gantry
4. Spud keeper
5. Load line
6. Ballast hold, both sides
7. Fuel tank (starboard)
8. Fuel tank (port)
9. 5T derrick boom (port)
10. 8T chain block (starboard)
11. Engine room
12. Crew space
13. Ladder shear stay
14. Ladder hoisting cable
15. Store
16. Dead space (both sides)
17. For ladder hoisting
18. For temporary ladder lifting
19. Oozer pump
20. Sludge detecting rod
21. Sludge probe and depth Probe, 1, 2, 3, 4 & 6
22. Oil, gas recovery hood
23. Lower underwater tv camera
24. Pollution prevention and waterproofing cover
25. Draghead type suction inlet
26. Sludge probe
27. Upper underwater tv camera
28. Maximum dredging depth - 18 M
29. Rib weld spacing
30. Barge loading pipe
31. Ballast hold (port), 50.2 M^3
32. Fuel tank, 34.0 M^3
33. Air discharge duct
34. Main generator no. 3
35. Ventilation duct
36. Main air compressor no. 2
37. Main air compressor no. 3
38. Harmful gas treatment apparatus
39. Sound attenuation chamber
40. Ladder motor
41. Swing winch
42. Swing motor
43. Pump B, 4.2 M^3
44. Pump A, 4.2 M^3
45. Direct pumping
46. Ballast hold (starboard), 50.2 M^3
47. Spud winch
48. Fuel tank, 24.3 M^3
49. Main generator no. 2
50. Ventilation duct
51. Main generator no. 1
52. Main air compressor no. 1
53. Ventilation duct
54. Vacuum pump
55. Sludge discharge pump
56. Fresh water tank, 115.1 M^3
57. Ladder winch
58. Store
59. Head
60. Conversion 75 KW
61. Sludge discharge pipe

Figure 31. The Oozer TAIAN MARU


PART OF SENSOR
TURBIDIMETER
PART OF MONITOR


◀ SLUDGE DETECTOR
SECONDARY CONTAMINATION MONITORING SYSTEM ▶

Appendix A-106

Figure A-32. Layout of turbidimeter, sludge detector and secondary contamination monitoring system on the TAIAN MARU

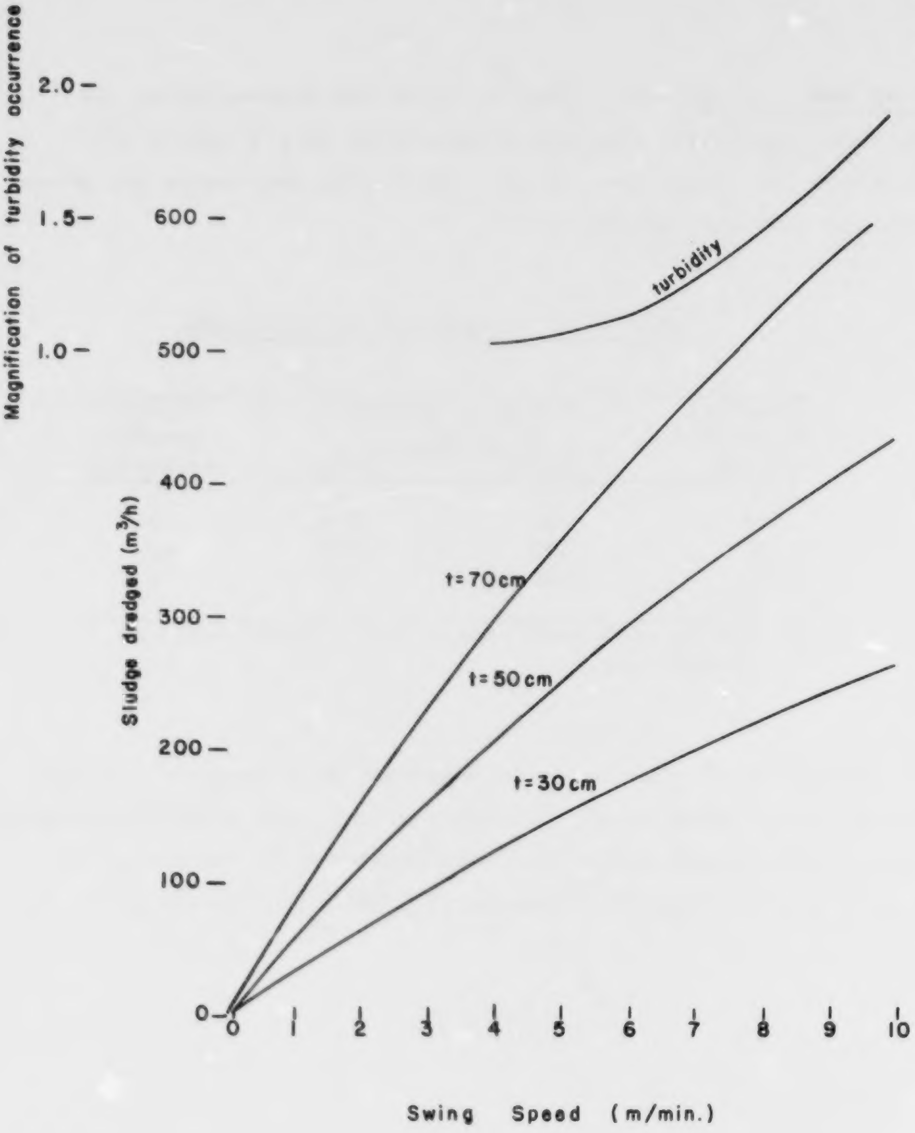
TAIAN MARU - Capability. Toyo Construction Company shows the following capability for this dredge based on a pressure of 7 kilograms per square centimeter. The sludge represents the amount of in-place sediment removed.

Table A-16. CAPABILITY OF TAIAN MARU

Pumping distance, meters	Dredging Quantity in m^3/hr		Sludge content, percent 1/
	Slurry	Sludge	
100	580	350	60
500	500	300	60
1,000	420	250	60

1/ Varies with condition of soil, swing speed of dredge, etc.

The capability of the dredge is dependent on a number of factors including the swing speed, thickness of cut, and turbidity created. The following graph shows this relationship when the dredge is operating with a slurry discharge of 1,000 cubic meters per hour.



(Notes) Sediment Type: Silt with the percentage of water content over 200%
Delivery distance is shorter than 1500m
TAIAN MARU discharging 1000 m^3/hr.
t = thickness of cut.
Magnification of turbidity = rate at which the suspended solids increase based on swing speed.

Figure A-33. Relation between sludge dredged, swing speed, and turbidity

TAIAN MARU-Applications. The Oozer can be utilized to dredge sediments containing toxic substances. The large Oozer has already dredged sediments in various parts of Japan containing mercury, PCBs and other deleterious material as shown in the following table.

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Table A-17. EXAMPLES OF TAIAN MARU OPERATIONS

Place	Construction Period	Bottom Condition	Undisturbed Moisture Content	Deleterious Material	Volume of Dredging Soil, m^3	Treatment
Iyo-Mishima Ehime Pref.	Apr - May '74	Sandy Silt	144	-	30,000	Direct discharge length 356 m Natural sedimentation, No treatment of return flow water
Iyo-Mishima Ehime Pref.	July, '74	Pulpwood	400 - 800	-	27,000	Direct discharge length 1,000 m Natural sedimentation, No treatment of return flow water
Chiba Port Chiba Pref.	Mar - May '75	Silt	300 - 400	Hg, Pb	40,000	Transport with barge, secondary pumping with centrifugal pump. Natural sedimentation
Yokkaichi Port Aichi Pref.	May, '75	Clay Silt	280 - 500	-	2,300	Transport with barge, Secondary pumping with centrifugal pump, Closed treatment
Takasago Port Hyogo Pref.	Aug - Dec '75	Silt	150 - 200	PCB	183,000	Direct discharge length 300-1,200 m Solidity, Removal of deleterious material
Sakaide Port Kagawa Pref.	Dec., '75	Sandy Silt	90 - 100	Hg	14,000	Direct discharge length 460 m, Natural sedimentation, Removal of deleterious material
Iwakuni Port Yamaguchi Pref.	Jan - Feb '76	Sandy Silt	100 - 200	-	31,000	Direct discharge length 300 - 800 m Natural sedimentation, No treatment of return flow water
Tokuyama Port Yamaguchi Pref.	Aug - Nov '76	Sandy Silt	50 - 300	Hg	145,000	Transport with barge. Natural sedimentation, No treatment of return flow water
Tokuyma Port Yamaguchi Pref.	Dec '76 - Feb '77	Sandy Silt	50 - 300	Hg, C_6H_{14}	1/	Transport with barge, Natural sedimentation, No treatment of return flow water
Yokkaichi Port Aichi Pref.	Apr '77 - Feb '78	Sandy Silt	280 - 500	Hg	2/	Discharge with booster pump. Natural sedimentation, No treatment return flow water

1/ Dredging area = 164,000 square meters

2/ Dredging area = 750,000 square meters

The following are performance record details on two projects. In the first project, sludge with a solid content of as much as 90 percent in the total apparent volume was transported through a pipeline extending about 365 to 1,000 meters. The pumps on the TAIAN MARU are not considered suitable for conveying sludge under pressure over a long distance. The material which was dredged was about 1.5 to 2.0 times higher in water content that that which lay on the seabed. (By comparison, the sludge dredged by a suction pump dredge varies from 4 to 9 times higher in water content than the material as it lies on the sea bottom.) This demonstrates that the Oozer Pump can remove sludge at a considerably higher density level than the volute pump which is generally used on the suction pump dredge. Consequently, there is less water to be treated at the disposal area.

PROJECT 1. Dredging of Sludge Containing Pulp Waste

This project involved about 100,000 cubic meters of sludge containing waste materials discharged from paper and pulp mills, sandy silt and their mixture.

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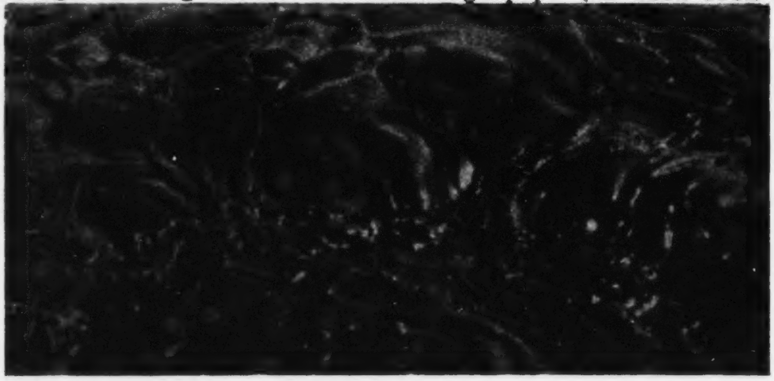
best available copy.

Item	Samples of Sludge	Sample 1	Sample 2
Work Period		Apr.-May '74	Jul '74
Classification		Sandy Silt	Pulp fibers
Absolute specific gravity of soil particles		2.6	2.0
Water Content (%)	Sludge on seabed	144	260
	After dredging	500	700
Sludge dredged (m^3/h)		350	465
Sludge content in apparent Vol. (%)		60	90
Pumping distance (m)		365	1,000

Notes:
- Given above are the average values.
- Classification of sludge in the case of No. 2 above is difficult, so it is designated as "pulp fibers"
- Sludge on the seabed was sampled by divers for comparison of water content
- The sludge content in the unit apparent volume was measured with samples taken from dredged sludge after leaving them for 48 hours to allow for precipitation.

(a) Sludge flowing out of the discharge pipe (as seen from above).



(b) Sludge flowing into a sedimentation pool.

Figure A-34. Dredging pulp waste with TAIAN MARU
(Nishi, Courtesy of WODCON VII)

PROJECT 2. Dredging of Sludge Containing Clayey Silt

Item / Samples of sludge		Sludge on seabed	Dredged Sludge
Work period			Nov '74
Specific gravity of particles		2.78	2.76
Unit weight (g/cm^3)		1.23 - 1.24	1.20 - 1.21
Water content (%)		1.45 - 1.50	180-190
Void ratio		4.258	5.46
Composition (%)	Gravel	0	0
	Sand	2	2
	Silt	62	64
	Clay	36	34
	Classification	Clayed Silt	
Sludge dredged (m^3/h)		300	
Sludge content in apparent Vol. (%)		96	
Pumping distance (m)		300	

Figure A-35. Dredging clayey silt with TAIAN MARU
(Nishi, Courtesy of WODCON V11)

The following figure summarizes the performance characteristics of the Oozer Pump in the previous two projects.

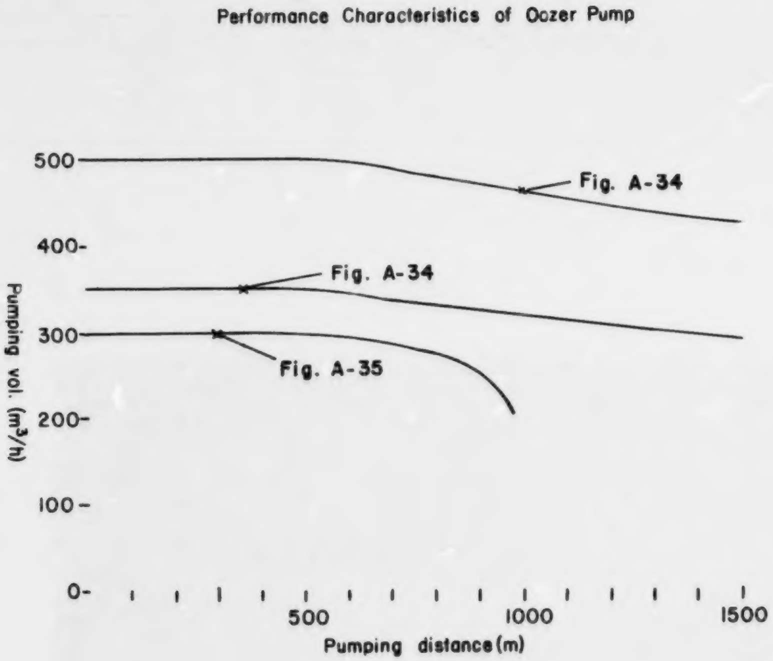


Figure **A-36** Performance Charateristics
of Oozer Pump
(Nishu, Courtesy of WODCON VII)

TAIAN MARU - Evaluation. The company states that the excavating capacity of the Oozer is almost the same as that of the cutterhead dredge for sediments containing a large amount of water. For sandy sediments or cohesive clays, the dredging capacity of the Oozer is less, due to the cutterless suction. Cutters can be attached to the suction head of TAIAN MARU, but its efficiency would still be only 50 to 70 percent of the conventional cutterhead dredge. Without cutters, it would be 30 to 50 percent. For example, dredging of a sediment containing 5 percent gravel, 45 percent sand, 35 percent silt, and 15 percent clay for the 1,000 cubic meter per hour model of the TAIAN MARU was 260 cubic meters per hour. However, for relatively short pumping distances, the Oozer discharges material with a much higher density than the conventional cutterhead dredge with a centrifugal pump. For long distance deliveries, a booster pump would be required when the percent of water in the sediment exceeds 350 percent. Generally, specialized dredges such as the Oozer are designed to carefully control the swing speed or thickness of sediments being dredged so as not to diffuse toxic substances (heavy metals, oil, etc.) contained in the bottom sediments. It is therefore not desirable to compare the two types of dredges--cutterless versus the Oozer suction--based only on the efficiency of sediment removal.

The Oozer delivers dredged material with solids varying from a minimum of 40 percent to a maximum of 70 percent and with an average of 30 to 50 percent. The percent of solids content varies with condition of the soil, thickness of sediment, swing speed, obstacles, etc. The percent of solids increases with silt and with a high percent of water content. It reduces when the sediments are clays or sand. The following table illustrates this.

Table A-18. OOZER PUMP DREDGE, 1000 m^3/h MODEL

Water content percent	Sediments	Solid content, percent
600	Organic	70 - 80
110	Sand with Silt	20 - 30

Where bottom sediments are not contaminated, the operation of the cutterhead dredge is less costly than the Oozer since treatment of the disposal area is not an important factor. However the cutterhead pumps far more water than the Oozer during dredging operations. Therefore where toxic sediments are dredged, the Oozer system could contribute a savings to the overall cost due to the treatment of a smaller amount return waters.

The Clean Up dredge owned by Toa Harbor Works Company and the Oozer TAIAN MARU owned by Toyo Construction Company are undoubtedly the two types of equipment most capable of dredging high concentrated sludge while causing the least amount of turbidity of all dredges presently available in Japan. For this reason, both were chosen for a dredging project at Yokkaichi Port. According to comments by Toyo and Takenaka, difficulties were experienced by Clean Up No. 3, the dredge chosen, due to clogging of the auger and suction inlet with plastics and other trash.

They state that the Oozer Pump includes a steel ball weighing 80 kilograms which serves as the suction valve that will crush any prospective obstruction so that there will be almost no clogging of the pump.

Small Oozer Dredge. Toyo Construction Company has developed a small portable Oozer which can be dismantled, transported, and reassembled at work sites to which it cannot be towed on water. The vessel hull is about 21 meters long, draws about 2 meters, and the dredging depth is 6 meters. The dimensions of the hull are subject to change according to conditions at the work site. The Oozer is cylindrical in shape and double barreled just like the larger dredge. The equipment for this portable dredge follows:

Oozer pump - Cylindrical, double barrel, negative pressure, pneumatic pumping type.

Air compressor - 17 $m^3/m \times 7\ kg/cm^2$ (1 unit).

Vacuum pump - -500 mm/Hg x 10 m^3/min (1 unit).

Main generator - 200 v x 100 kva (1 unit).

Winches
  Ladder winch 5T x 15 m/min (1 unit).
  Swing winch 8T x 1-10 m/min (2 units).
  Spud winch 3T x 15 m/min (2 units).

1. Ladder Winch
2. Oil, Gas Flotation Prevention Hood
3. Dredging Depth
4. Barge Operation Winch
5. Barge Operation Winch

6. Restroom
7. Oozer Pump Base
8. Main Air Compressor
9. Gas Scrubbing Apparatus
10. Direct Pumping
11. Main Generator
12. Hydraulic Pressure Pump Unit
13. Vacuum Pump Unit
14. Pilot House
15. Sludge Pipe
16. Winch Base
17. Swing Winch

18. Swing Width
19. Spud
20. Barge Loading
21. Barge Operation Winch
22. Barge Operation Winch

Photographs of the small Oozer follow.

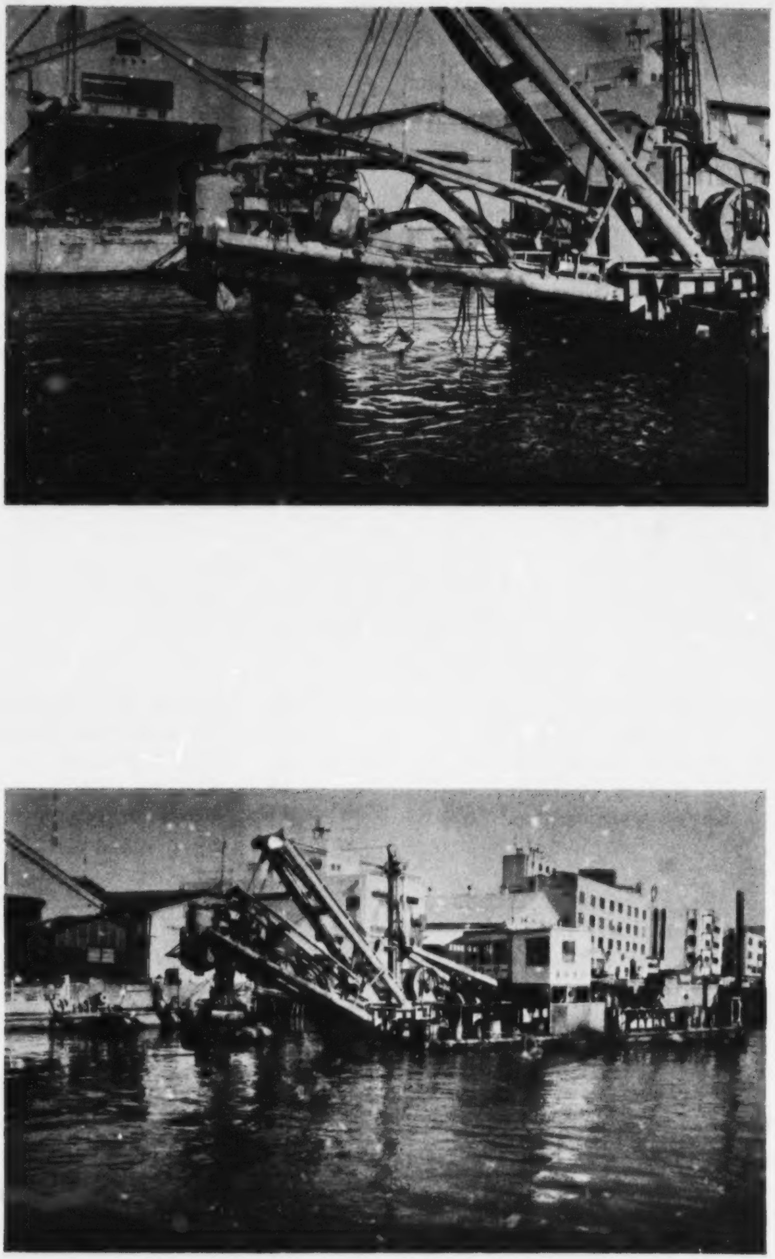


Figure A-37. Small Oozer dredge

The Oozer has the following capability.

Table A-19. CAPABILITY OF SMALL OOZER

Pumping distance (m)	Slurry dredging quantity (m^3/hr)	Soil dredging quantity (m3/hr)	Apparent sludge content 1/
100	100	70	70%
500	90	63	70%
1,000	80	56	70%

1/ Sludge content can vary from 30 - 70 percent

According to the company, its capability, insofar as secondary pollution is concerned, parallels the larger Oozer. The small Oozer can suck a high concentration of sediment, thus requiring less volume in the disposal area. Since the suction and discharge of the sediment are controlled by upper and lower limit detecting rods inside the pump, sediment of nonuniform properties can be dredged with high efficiency. Also special suction inlets permit it to dredge a wide range of clayey and sandy soils.

The following information shows the record of performance on one job.

Place - Tokyo Takahama Canal
Period of Work - March 1976; Jan - Mar 1977
Dredged Quantity (m^3) - 1,240; 8,056
Soil Thickness (m) - Av. approx. 0.75 (min 0.3)
Soil - Sandy silt
Natural Water content (%) - 220-400
Capacity (m^3/hr) - Av. 80
Sludge Content (%) - Av. 40
Secondary Treatment - Direct loading on sealed barge followed by disposal at fill area

On 13 March 1978, personnel from the Environmental Protection Agency and Corps of Engineers visited the site of the small Oozer dredge in Shibaura Canal in Japan. This project is being financed by the Minister of transport in Tokyo. The contractor is Toyo Construction Company. The project was initiated in December 1977 and it will be completed on 31 March 1978, a total of 110 days. The volume of dredging is about 36,000 cubic meters. Natural depth in this channel is about 4 meters and the barge with the small Oozer Pump draws about 2 meters.

In keeping with the portable design of the small Oozer, the barge is makeshift with the spuds welded on the back as well as on the operating bridge. It has one generator and an air compressor. Both are temporarily secured on the dredge. Four barges receive the dredged material and each barge carries about 200 cubic meters. A total of about nine barge loads are made in a day to the disposal site. During the observed operation of the Oozer dredge, there was absolutely no turbidity visible on the surface. By comparison, a tug passed the dredge and the turbidity that was caused by the tug was tremendous. Visually, this was an extremely clean and efficient operation.

Takenaka Sludge Treatment System. A method developed by Takenaka Komuten Company can stabilize polluted sediments in situ in rivers, on the sea bottom, or in a disposal site. Treatment materials used in this stabilization process include combinations of portland cement and various types of admixtures depending on the nature of the sludge and pollutants involved. The strength of the sludge increases with time depending on the water content and variety of treatment materials. It can then be utilized, for example, in land reclamation.

This system has been used in the following three ways:

a. Treatment of dredged sludge. Sludge is dredged, treated with a solidifying agent in a mixing plant, and then disposed.

b. Surface layer solidification. This procedure permits treatment of sludge in situ down to 3.5 meters. When the thickness of the mud layer is great, only the top portion needs to be solidified.

c. Deep Chemical Mixing Method. This procedure strengthens the foundation ground where offshore structures are constructed on soft sea bottom. It can be used for the solidification of sludge down to a thickness of about 47 meters.

Performance of the system in connection with items (a) and (b) above is shown in the following table.

Table A-20. PERFORMANCE RECORD OF TST SYSTEM

Material	Solution	Perfomance record from 1973 to date 1/
Sludge deposited in water	Dredging the sludge, mixing it with hardeners, and then filling in areas	17 projects involving 460,000 cubic meters
Discharges from factories and sewage treatment plants	Mixing discharges with hardeners before deposition	7 projects involving 14,500 cubic meters
Mud of high water content already deposited in some land area	Mixing mud with hardeners and solidifying it in situ	1 project involving 20,000 cubic meters in solidification of a sludge pond

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1/ Twenty-two of these projects contained some type of harmful substance.

Hardeners in TST System. As previously stated, the purpose of treatment is to solidify soft mud in a form easy to handle and to stabilize or chemically fix such harmful substances as mercury, chrome, or cadmium. Heavy metals are not easily dissolved in an alkaline environment and sludge solidified with cement-base material and subject to the leaching test specified by the Japanese Environmental Agency show a small quantity of leached substances. Therefore sludge deposits which contain harmful substances in excess of prescribed levels and which cannot be treated in place must be removed. When removed, the sludge must be treated before or during the disposal process to prevent leaching of harmful substances.

The Takenaka Sludge Treatment (TST) method was started by the company in 1971 and centered around solidification and fixation by cement-based solidifying material. In addition, there are special additives for stabilizing harmful materials. They are referred to as follows:

Table A-21. HARDENERS IN TST SYSTEM

Hardener	Type	Description	Attained Comprehensive strength
C series	C-7	Powder effective with sludge of high inorganic content	1 to 10 kg/cm^2
	C-11	Powder with cement as base and used with an additive. Used with material of high organic content.	0.5 to 3 kg/cm^2
T-B series		Cement base with and without additive. Used on material with high organic content.	
T-A series		Inorganic powder or liquid. Additive for stablizing harmful substances in sludge containing very large quantity of heavy metals. Does not add to strength.	
T-C series		An organic material in liquid form. Used with other solidifiers like T-A series, of harmful substances such as Kepone, PCB, etc.	

The following results provided by Takenaka show how noxious materials in sludge were fixed with solidifying chemicals by the TST system prior to use of the sludge as a resource.

Table A-22. NOXIOUS MATERIAL FIXATION BY TST METHOD
(Values in ppm)

Sludge	Cu	Zn	Cd	Hg	Pb	Cr	PCB
Before Treatment	21.4	101	0.226	42.5	-	-	-
After Treatment	0.13	0.026	ND	ND	-	-	-
Before Treatment	72.6	-	0.512	56.6	-	-	-
After Treatment	0.16	-	ND	ND	-	-	-
Before Treatment	-	691.2	8.2	-	-	405	-
After Treatment	-	0.1	ND	-	-	ND	-
Before Treatment	-	1218	107	38.9	1946	998	-
After Treatment	ND	-	ND	ND	ND	ND	-
Before Treatment	-	-	-	-	-	-	2891
After Treatment	-	-	-	-	-	-	ND
Before Treatment	-	-	-	-	-	-	583
After Treatment	-	-	-	-	-	-	ND

ND = Non-detectible

Planning and Executing the TST System. The following table shows the details involved with completing such a system.

Table A-23. OUTLINE OF TST METHOD

Item	Description
Investigation	Geology, water phase, biology, meteorology Surveying (distribution, thickness, depth of sludge) Comparison with removal criteria Sludge analysis (physical properties, composition)
Experimentation	Quantification of harmful substances, Solidification experiments with hardening agents Leaching tests of solidified material
Planning	Overall plan Execution plan Cost study Machine development Secondary pollution countermeasures
Design, Estimation	Execution plan Working design Estimation
Work Execution	Temporary works Dredging Conveying Treatment Land development Quality control Work stage management Safety and sanitation control
Inspection	Confirmation of removal site Inspection of developed land

Treatment of Dredged Sludge at Takasago. The Takasago Nishi Port is a project which was carried out under the TST method. It consisted of dredging 170,000 cubic meters of sludge on 194,000 square meters of the sea bottom contaminated with PCBs and placing it in an area of 50,000 square meters. The period of work was from July 1975 to March 1976. Conditions specified were as follows:

a. Prevention of muddying the seawater during dredging,

b. Reduction of PCB content of bottom sediments after dredging to 10 ppm or less,

c. Solidification treatment of sludge,

d. Prevention of leaching of harmful substances (mainly PCB) from treated sludge,

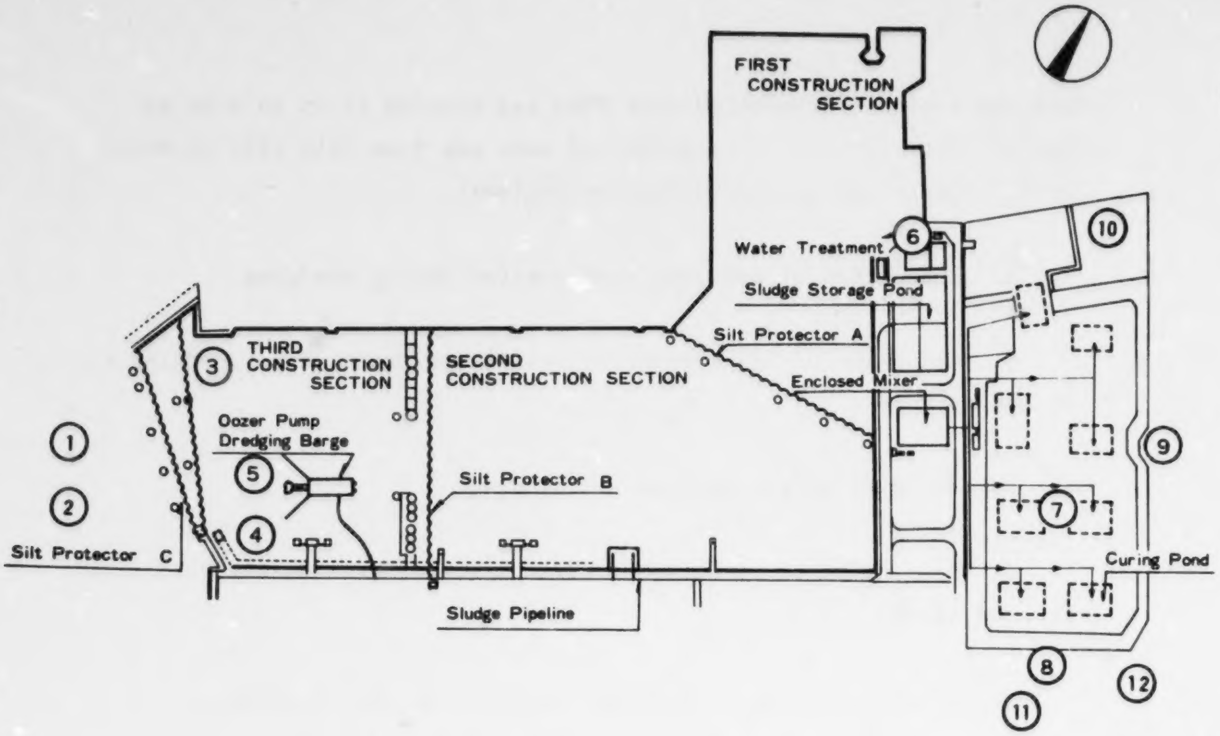
e. Purification of waste water produced during treatment,

f. Complete prevention of propagation of contaminants from reclaimed land,

g. Monitoring of contamination during work, and

h. Measures for environmental protection such as odor and dust prevention.

The sludge consisted of very fine particles and excessive water. Continuous research and analysis had to be accomplished during the preliminary planning stage. The work consisted of dredging, sludge transport, solidification treatment, and transport and filling with the treated sludge. Plan of sludge treatment and project details are shown in the following figures.


FIRST CONSTRUCTION SECTION
THIRD CONSTRUCTION SECTION
SECOND CONSTRUCTION SECTION
Water Treatment
Sludge Storage Pond
Silt Protector A
Enclosed Mixer
Oozer Pump Dredging Barge
Silt Protector B
Silt Protector C
Sludge Pipeline
Curing Pond
①
②
③
④
⑤
⑥
⑦
⑧
⑨
⑩
⑪
⑫

Horizontal Plan of Sludge Treatment at TAKASAGO Nishi Port

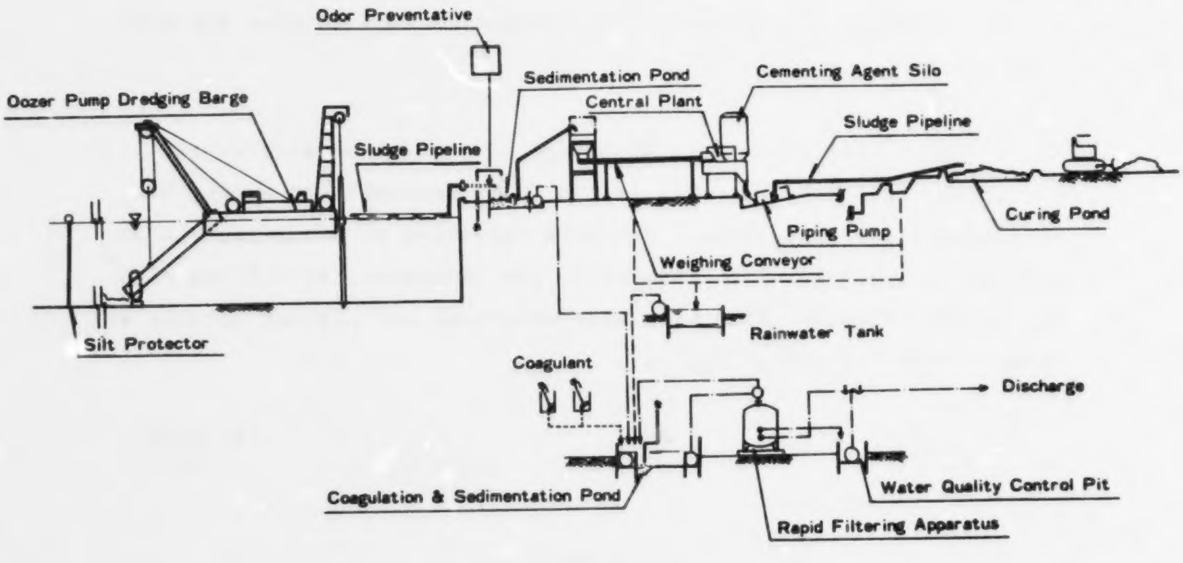

Odor Preventative
Sedimentation Pond
Cementing Agent Silo
Central Plant
Oozer Pump Dredging Barge
Sludge Pipeline
Sludge Pipeline
Curing Pond
Piping Pump
Weighing Conveyor
Silt Protector
Rainwater Tank
Coagulant
Discharge
Water Quality Control Pit
Coagulation & Sedimentation Pond
Rapid Filtering Apparatus

Figure A-38. Project Details

The location of monitoring points is shown in the upper sketch of the previous figures. In order to insure that the requested conditions were being satisfied, the monitoring program shown in the following table was established.

Table A-24. MONITORING PROGRAM FOR DREDGING AND SOLIDIFYING AT TAKASAGO

Survey Location			Before Construction		During Construction		After Construction	
			Survey Item	Survey Frequency	Survey Item	Survey Frequency	Survey Item	Survey Frequency
Water Area at large	Basic Monitoring (2 sites, 2 locations per site)		PCB PH COD DO Turbidity	Not less than 20 times total per item	PCB PH COD DO Turbidity	Once per day for all items	PCB PH COD DO Turbidity	not less than once
Dredging Area	Supplementary Monitoring (2 sites)							
	Work Site Surroundings Monitoring Point	Water Quality	-	-		(in case of need)	-	-
		Bottom Material	PCB	Not less than once	-	-	PCB	Not less than once
Disposal Site Surroundings	Rainwater, Waste water Management (1 site)		-	-	PCB Turbidity	Once per week	-	-
	Treated Sludge		-	-	PCB (Leaching Test)	Once per week	PCB (Leaching Test)	Not less than once
	Underground Water (3 sites)		PCB	Not less than 5 times total	PCB	Once per week	PCB	Not less than once
	Atmosphere		-	-	PCB Dust	Once per week	-	-

During the project, special care was given to the safety of the workers. Following completion of the work, PCB contamination was removed from Nishi Port.

Dredging and Solidifying at Kurosaki. On 10 March 1978, representatives of the Environmental Protection Agency and Corps of Engineers visited the maintenance dredging works of Mitsubishi Kasei Company at Kurosaki Factory. This was a TST system application by Takenaka Komuten Company. The area had been the site of an old steel mill and it had discharged a tremendous amount of coal ash into the waterway. There were also other pollutants in this vicinity. The operation included sealing the area with a silt screen that floated at the top and was anchored at the bottom. The river was monitored on the outside of the curtain at three locations and also one-half mile downstream. No change in water quality was found during this operation.

Five methods of dredging were employed on this one job. The closed grab bucket with waterproof seal was the main dredge used. The total amount of material dredged was about 10,000 cubic meters. It was placed on a barge and towed to a pier where a clamshell unloaded the material into a hopper. Next a belt conveyed the material to a mixing plant. On the way to the plant, it was weighed to establish the amount of additive required. After the mixing operation, the material in heavy slurry form was put on a second conveyor belt and taken to three holding bins. It usually stayed in the bins for 3 days before being truck hauled to a landfill. Excess water was removed and sent to the waste water treatment plant.

This process is essentially the same as the one used at Takasago. One can appreciate the comprehensive studies that the Japanese have done to minimize secondary pollution that can occur from an operation of this type. For example, even contaminated runoff was treated before it was allowed to enter the natural environment.

TST Surface Layer Solidification. The TST surface layer stabilizer is a machine for applying solidification treatment to the surface layer of sludge using a cement-base hardener. The following table provides data thereon.

Table A-25. TST SURFACE LAYER STABILIZER

Item		Amount
Sludge Treatment Thickness		3.5 m max
Mixer	Electric Motor	15 kw x 4 p, 2 units
	Rotating Speed	58/42.5 rpm (sprocket change)
	Lifting-Lowering Speed	6.0 m/min max
	Lifting - Lowering Stroke Cylinder	2200 mm
	Chain Block	2200 mm
	Transverse Travelling Speed	3.0 m/min
Mixing Blades	Number	2
	Diameter	1.6 meters spaced at 4-6 inches apart
Hydraulic Unit	Electric Motor	7.5 kw x 6 P, 1 unit
	Applicable Pressure	140 kg/cm^2
Power Supply		AC 440 V, 60 Hz
Weight		32.8 tons
Including Pontoons		60 tons
Size of Machine		28 m x 12.2 m

The following figure shows a photograph thereof.

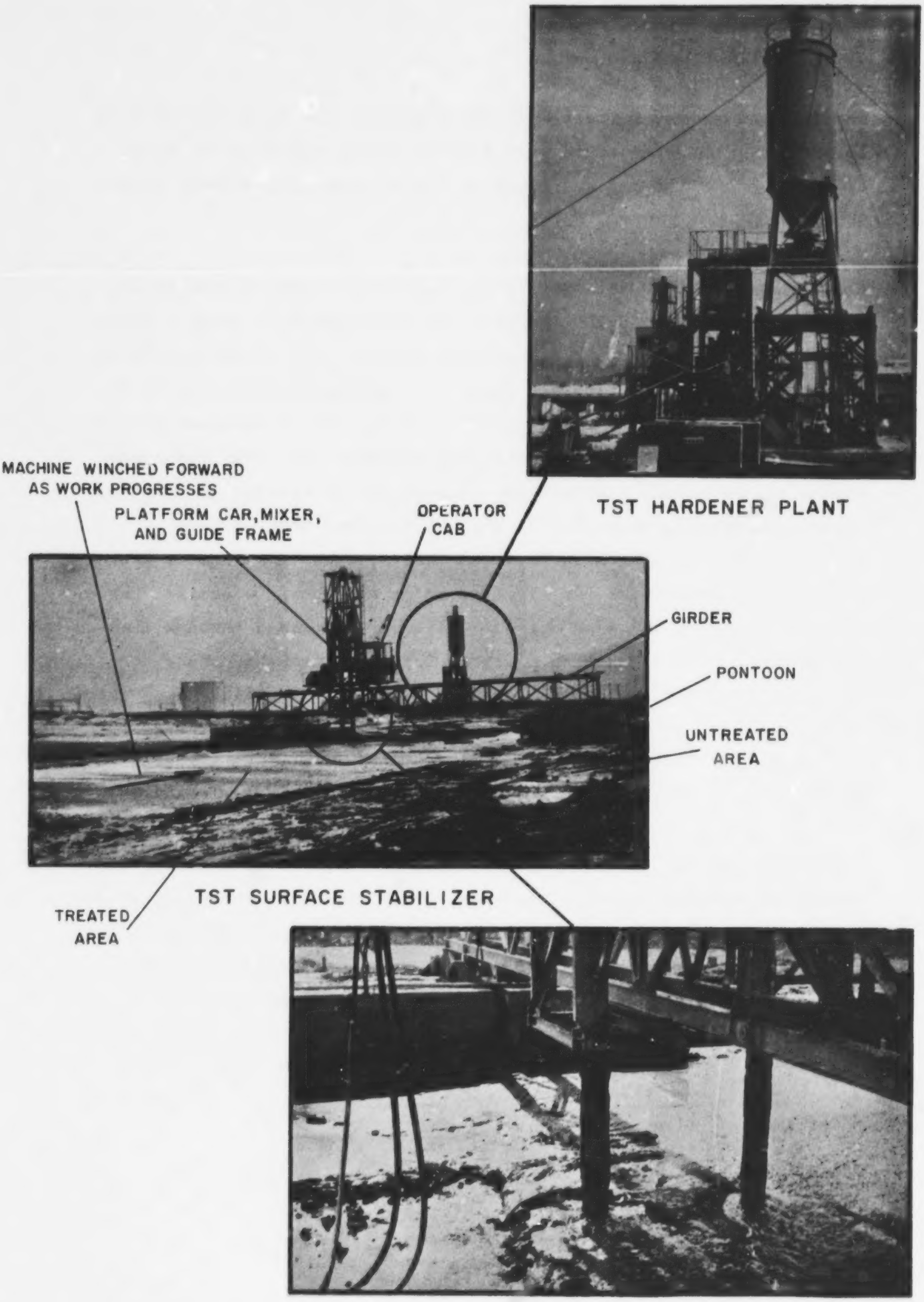

MACHINE WINCHED FORWARD AS WORK PROGRESSES
PLATFORM CAR, MIXER, AND GUIDE FRAME
OPERATOR CAB
TST HARDENER PLANT
GIRDER
PONTOON
UNTREATED AREA
TST SURFACE STABILIZER
TREATED AREA
MIXING BLADES

Figure A-39. TST SURFACE LAYER STABILIZER EQUIPMENT
(Courtesy of Takenaka Komuten Co., Ltd.)

The TST surface layer stabilizer was developed for installation both in water and on soft ground with a draft during operation in water being 0.5 m and the contact pressure during operation on soft ground 0.06 kg/cm^2.

As indicated in the previous figure, two fully inclosed, box-shaped pontoons arranged at right and left are connected by a trussed girder having two rails on top. Each pontoon is comprised of one main float and two supplementary floats. There is a mobile platform car on the girder which travels on wheels. The platform car is equipped with a mixer guide frame, hydraulic unit, and operator cab. The transverse travel of the mobile platform car is achieved by winding in wire rope rotating a winding drum that is chain-driven and powered by a hydraulic motor. (The mixer has two shafts, each individually driven by chain drive with its own electric motor and speed reducer.) These shafts are hollow and a cement-base hardener is passed through them and discharged on the mixing blades. The two mixer shafts are supported by a frame which is capable of travelling up and down inside the guide frame by hydraulic cylinder and chain block. Shifting of the entire TST surface layer stabilizer is done by a winch installed on land (or on a float).

Stabilized soil of the required strength is obtained by altering the amount of hardener added in accordance with the soil properties of the ground to be treated. Since the original ground is solidified in situ, it is not necessary for dredging, removal, and disposal of sludge to be done; therefore, there is little risk of water contamination. Work may be performed on land or in water.

Furthermore, work is possible under conditions (such as extra soft ground) where conventional work methods are restricted. Unlike conventional methods in Japan which use large quantities of sand, the in situ ground is utilized, thereby conserving a resource. Although depending on the water content and the rate of addition of hardener, the treatment capacity has been between 70 and 100 cubic meters per hour.

Further investigations remaining to be performed with the TST surface layer stabilizer follow:

a. Study the mixing mechanism of sludge and cement-base hardener and the effect thereof in definite terms.

b. Establish design methods for two layered ground (surface layer of soil and top of sludge) based on timing of land use after solidification treatment and purpose of land use.

c. Establish method for joining solidified (stabilized) soil (joints between soil treated that day and the previous day, and between that day and about one week previously), and determination of joint strength.

d. Reexamine pontoon configuration (when shifted over soft ground, sludge is collected at pontoon fronts).

e. Develop work execution method and equipment for edge treatment (pontoons are ineffective at edges of sludge deposit area making solidification treatment difficult).

f. Develop remote control operation of TST surface layer stabilizer for sludge treatment where hazardous substances (gas, odors, etc.) are produced.

TST Surface Layer Solidification Projects. A surface layer hardening project was accomplished at the Tokuyama Soda Sludge Reservoir in 1977. A factory had emitted 100,000 cubic meters of various kinds of sludge and stored it in a reservoir about 12,000 square meters. In order to utilize the area, a TST surface layer stabilizer on pontoons was floated on the sludge reservoir to solidify the surface layer to a thickness of about 1-1/2 meters. Soil was placed over this thereby changing the sludge reservoir into a two-layered ground area, a surface layer of soil and below this the hardened sludge. A loading test was made by surcharging the soil. It was verified that the stability analysis developed by Takenaka and the results of the loading test were in fairly good agreement. Thus, if it is costly to solidify all of the sludge in a reservoir, hardening only the surface layer is an effective solution.

On 9 March 1978, the Environmental Protection Agency and the Corps of Engineers team visited a TST solidification project on the Tokkaku River. The objective of this project was to stabilize a layer of mud and then build a structure for a drainage project and pumping station thereon. The area covered 6,500 square meters and a total of 21,000 cubic meters was to be stabilized.

The area was marked off in sections, each 3.2 meters by 17 meters with an average thickness of 3.2 meters. Two parallel sheet piling structures encompassed the entire site. The steel sheet piling was driven into good foundation on the bottom and the soil solidification method was used at the top to create a part of the impervious core. This will have sufficient capacity to insure that failure will not occur. The TST machine started with the blades at the top of the sludge. The blades took 12 minutes to go down about 3.2 meters and then to come up again for a full cycle. The machine was then moved 40 centimeters and the mixing cycle took place again. It took 4 hours to complete one section. Then the machine was winched forward and the operation started again. The additive was mixed with concrete at the mixing plant and about the same amount of water by weight was added. It was then pumped to the top of the stabilizer and discharged at the bottom of the blades into the sludge. It was estimated that by using this procedure there was a savings in time of completion and cost of construction. The trade name of the additive was Puzzolith. About 30 kilograms of the additive was added to the weight of the sludge in each section. Master Builders of Chicago currently manufactures this additive in the United States.

On 11 March 1978, the team visited Tokuyama and inspected the completed Tokuyama Soda Sludge Reservoir. Originally the depth of sludge had been about 7 meters. Here the TST project hardened about 1-1/2 meters. On top of the completed project 1/2 meter of soil from the mountains was hauled in. The foundation created by this TST project was sufficient to support a two story building. The Japanese opened a square pit down to the top of the hardened material. A backhoe then dug through the treated 1-1/2 meters to the existing sludge below. The sludge was in its natural state, very runny, and would offer no support.

Takenaka Deep Chemical Mixing Method (DCM). With 4/5 of the country covered by hills and mountains, Japan has had limited usable land space, so much so that the effective use of ocean space is of vital importance.

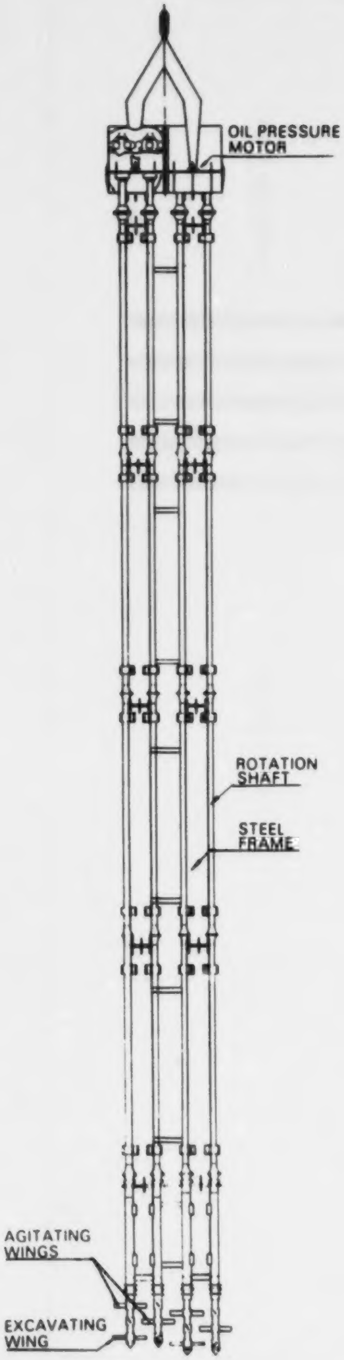
As the great majority of Japanese coastal cities stand on alluvial clay, the bulk of harbor facility construction costs go into soil improvement work. For such projects, sand has been used extensively. In recent years, however, it has become increasingly difficult to rely on conventional methods as they require the proper disposal of the excavated soft soil and good supply of high quality sand for the prevention of pollution and preservation of the environment. Along with changes in the public standards of environmental protection and the needs of harbor structures, the following problems have arisen:

a. From the standpoint of environmental protection, it has become difficult to gather sand on land. The cost of sand has therefore risen.

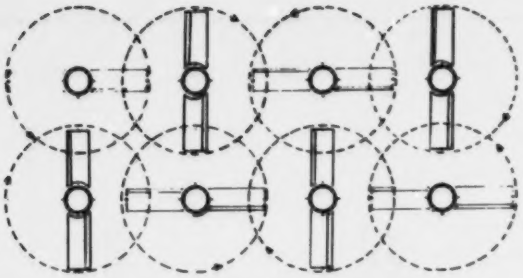
b. With an increase in size of harbor structures and their location on softer ground, there is a trend for increasing the depth of stabilization and the replacement ratio of sand.

c. Regulations have become more strict relative to environmental pollution accompanying the dredging of soft cohesive sand and disposal of dredged soil.

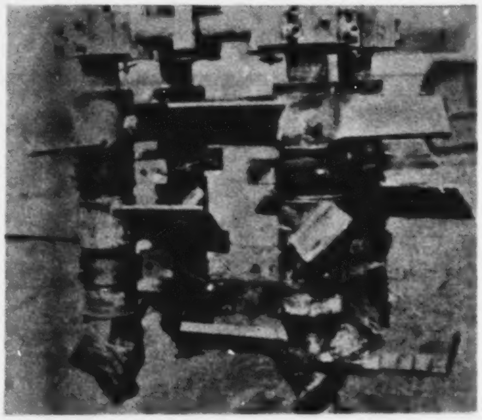
Under the guidance of the Institute for Technical Research of Ports and Harbors, Transportation Ministry of Japan, Takenaka recently developed the DCM (Deep Chemical Mixing) method which is designed to solidify soft ground to a depth of as much as 47 meters. This new method consists of thoroughly mixing, in situ, cohesive soil deposited on the sea bottom with a hardening agent (cement based, lime based, etc.) so as to stabilize ground at the sea bottom utilizing chemical solidification action. The deep chemical mixing equipment is 40 meters long, 24 meters wide, and has a draft of 3.2 meters. It weighs 142 tons. The height of the tower is 53 meters. There are 8 blades paired with 600 kilowatts of power. The blades cover an area 1.5 by 3 meters or about 4.5 square meters. The following figures contain pertinent sketches of the operation. Takenaka has another DCM under construction and is now designing a machine that will be able to operate to a depth greater than 47 meters.


OIL PRESSURE MOTOR
ROTATION SHAFT
STEEL FRAME
AGITATING WINGS
EXCAVATING WING

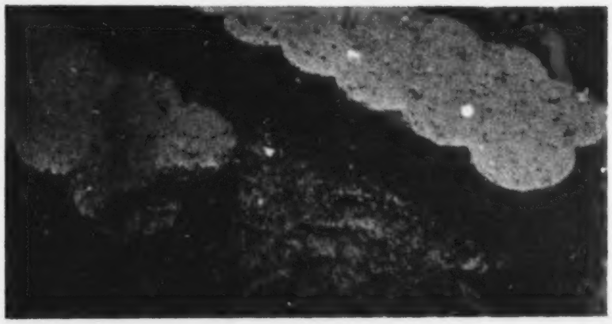
DCM OPERATION
Deep Chemical Mixer



SHAPES AND ROTATING DIRECTIONS OF AGITATING WINGS



MIXING WINGS



SOIL CLEANED AWAY TO EXPOSE TREATED AREA

Figure A-40. Deep Chemical Mixing Equipment

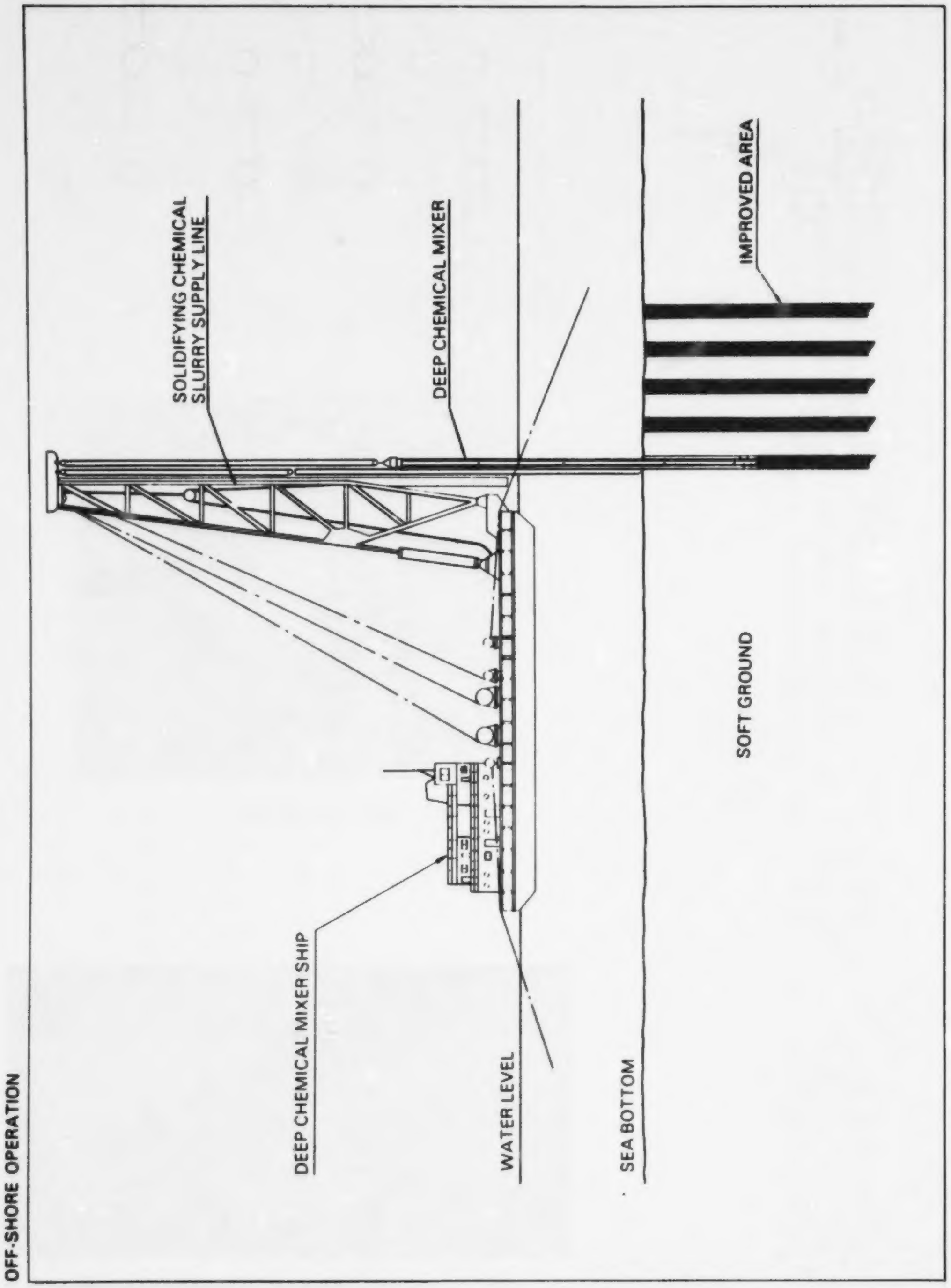

OFF-SHORE OPERATION
DEEP CHEMICAL MIXER SHIP
WATER LEVEL
SEA BOTTOM
SOLIDIFYING CHEMICAL SLURRY SUPPLY LINE
DEEP CHEMICAL MIXER
SOFT GROUND
IMPROVED AREA

Figure A-41. Deep Chemical Mixing Equipment

According to the company, some of the advantages of the DCM method are:

a. The DCM method solidifies the soft ground to the required strength by varying the ratio of solidifying chemical to soil to suit the properties of the soil.

b. With this method, a continuous wall made of adjacent pillars can be built as one body to improve soft ground.

c. Ground improvement can be carried out on land or in the sea.

d. Since the ground is solidified in situ without dredging, removal, or disposal of sludge, the operation will not cause water pollution resulting from a dredging and disposal operation.

e. The DCM solidifies the soft ground in situ without having to fill in huge quantities of sand as with conventional methods.

Harbor structures such as breakwaters, dikes, quay walls, and mooring wharves are long in one direction and stability against loads perpendicular to this direction is difficult to achieve. A pile type configuration of treated soil supporting the superstructure is feasible when horizontal loads are small. However when horizontal loads are large, shearing deformation will be excessive. Consequently, a wall type stabilization was devised based on the same concepts as for a hear wall. This can be done by a contiguous pile type stabilization. A sketch of such a form is shown in the following figure.

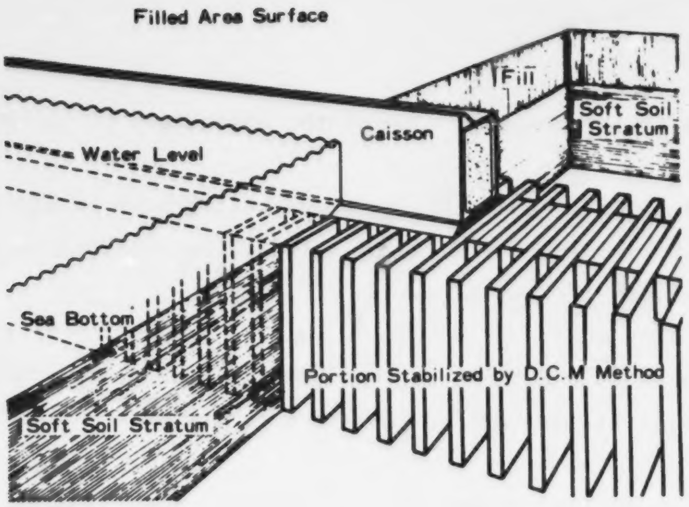

Filled Area Surface
Fill
Soft Soil Stratum
Caisson
Water Level
Sea Bottom
Portion Stabilized by D.C.M Method
Soft Soil Stratum

Figure A-42. Fundamental Form of Quay Wall and Stabilized Ground By D.C.M Method

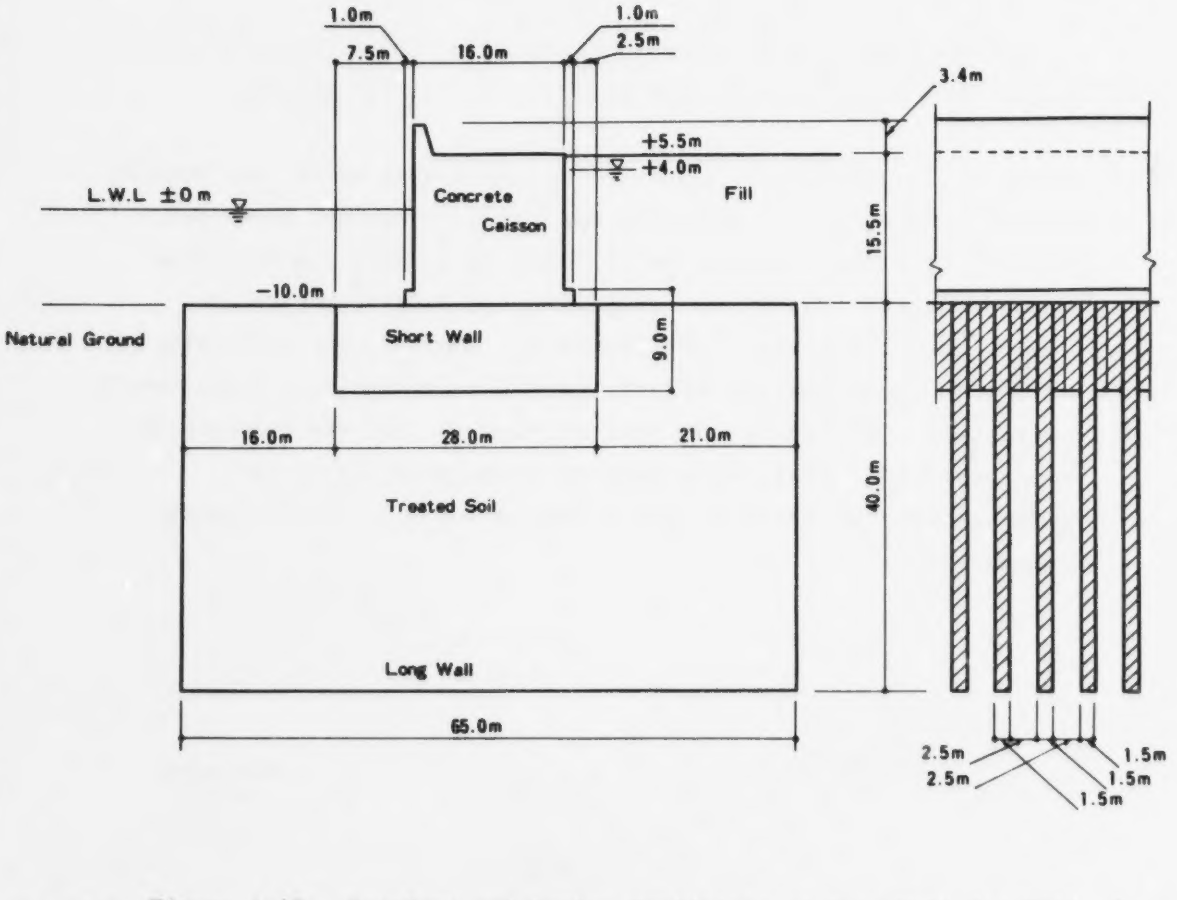

1.0m
7.5m
16.0m
1.0m
2.5m
3.4m
+5.5m
+4.0m
L.W.L ±0 m
Concrete
Caisson
Fill
15.5m
−10.0m
Natural Ground
Short Wall
9.0m
16.0m
28.0m
21.0m
40.0m
Treated Soil
Long Wall
65.0m
2.5m
2.5m
1.5m
1.5m
1.5m

Figure A-43. Sections and Design Conditions of Quay Wall for Fill of a Waste Disposal Plant

317<

A typical example of the DCM process follows. The previous figure shows a standard section of a quay wall. Due to a depth of water of 10 meters plus the utilization of municipal wastes and river sludge as backfill, the extent of stabilization is fairly large--to a depth of 40 meters and a length of 65 meters. Stabilization with the DCM method is provided by a wall 1.5 meters thick spaced 2.5 meters apart. The short walls reinforce against shear and help alleviate stress concentrations at the top of the walls due to the superstructure loads.

On 13 March 1978, the Environmental Protection Agency and Corps of Engineers team were briefed by officials of the Port and Harbor Waste Disposal Office at Yokohoma Bay. The team was told that there was requirement to dispose of 10 million cubic meters of waste per year and that 60 percent is deposited in waste areas in Tokyo Bay. These waste areas are artificial islands creased by constructing walls in the bay and then filling the area created within these walls with waste material. Waste area no. 1 is 77 hectares (190 acres). Waste area no. 2, when completed, will be 122 hectares (300 acres) and will be outside of the breakwaters so that the concrete walls will be subjected to considerable stress. The DCM is beginning to be used under these walls. The clay at the sea bottom must be stabilized to a depth of 42 meters below sea level. The sea is from 5 to 10 meters deep.

After the briefing, the team moved by boat to the new island being constructed for waste area no. 2 and inspected the DCM in operation. There is normally a crew of 12 persons per shift--4 persons to operate the concrete mixing plant, 3 persons in the wheelhouse of the DCM, and 2 persons to handle the lines and other equipment. The machine can more up and down 7 times during a 9-hour shift. It stabilizes about 4.5 square meters during each operation. At this site the additive was 15 percent of the weight of the material. This was extremely high because of the strength needed to support the wall to be built thereon. The DCM mixture attains a workable strength in 4 weeks and reaches its maximum in about 1 year.

SUMMARY OF TOKYO TRIP PERTINENT TO BAILEY BAY

The entire day, 14 March, was devoted to an analytical discussion including questions and answers concerning the Takenaka and Toyo processes and equipment and the projects which the U.S. team had visited during this trip to Japan. This meeting included Toyo Construction Company representatives and a number of technicians from Takenaka so that all processes could be discussed and questions could be answered.

A discussion relative to the Oozer Pump concerned the draft of the barge versus the shallow water of Bailey Bay which is 6 inches to 3 feet in depth. It was stated that the small Oozer had been used in 2 feet of water in Japan. From the discussion, it was concluded that without question the small Oozer dredge can and is suitable for the Kepone operation in Bailey Bay. The depth could be adjusted upward if a series of floats to make up the Oozer barge were used. Also the generator or air compressor could be put on separate units, thereby again decreasing the overall depth of the Oozer barge. The head could be redesigned in order to provide maximum efficiency during the operation in Bailey Bay.

The discussion then turned toward the lack of turbidity caused by the Oozer Pump. The U.S. team asked for backup data for turbidity information contained in the Toyo briefing booklet. It will be supplied after clearance with the Japanese Government.

The following is a list of equipment required for the small Oozer Pump.

Items of Equipment Necessary to Transport to the U.S.

a. Oozer Pump (body and suction equipment)

b. Vacuum Pump Unit

c. Operation Stand Unit (control panel)

d. Gas Purifier

e. Ladders (as required)

f. Control Valve Unit for Oozer Pump

U.S. Furnished Items

a. Hull (Unifloat)

b. Winches

c. Generator

d. Air Compressor

e. Tanks (fuel, water, air receiver)

f. Spuds

Laboratory results of the effects of the TB solidifier on the sludge samples sent to Japan from Bailey Bay were presented.

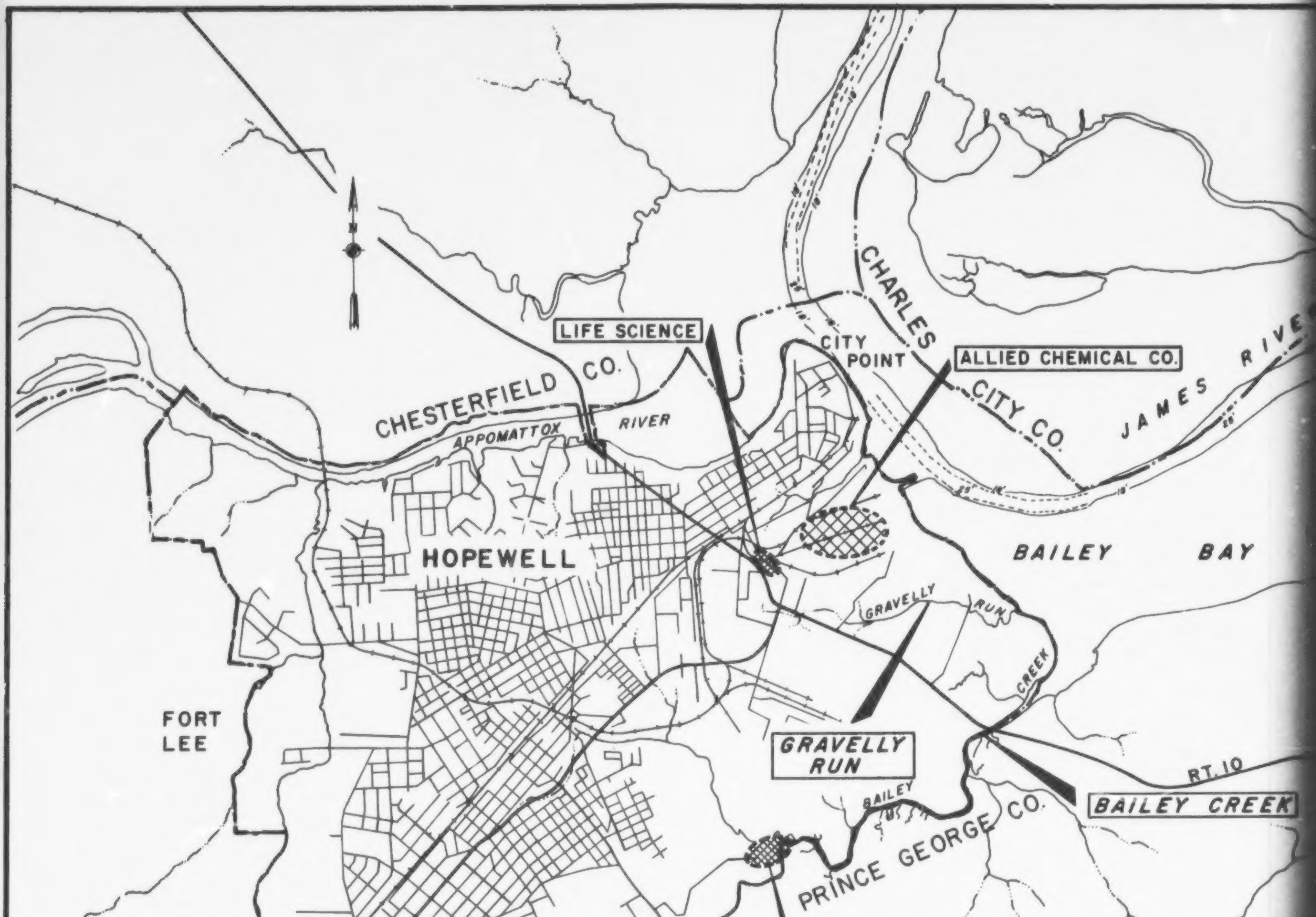
It was stated that the amount of sample material received thus far was not sufficient to do adequate testing and it was requested that additional samples of sludge from Bailey Bay be sent to Japan.

The U.S. team was told that there has been some difficulty in obtaining satisfactory results because of the very fine sand in the sludge. This creates a more difficult leaching problem with Kepone concentration being higher than otherwise would be evident. The tests have been performed with several different chemicals and under a number of different conditions, with no final results as yet relative to the fixing of Kepone. It is felt that the problem could be solved in the laboratory so that very little leaching would take place from the solidified sludge of Bailey Bay. Discussion ensued concerning the possible sites for a disposal area in Bailey Bay. Discussion then centered on the depth of treatment of the sludge. If 100 percent of depth in the disposal area is treated, then the cost would be extremely high. The depth to be treated and strength required will determine the treated soil thickness. From previous work done by the laboratory, if there are 10 meters of sludge, the 3.5 meters at the top usually have a strength of 0.75 kilograms per square centimeter or 1,500 pounds per square foot.

The Japanese stated that when treating the bottom of Bailey Bay in situ, if the water content of the bottom sediment is 75 percent in the top layer, then about 5 centimeters of the surface may not be solidified. If the water content is higher than 75 percent, then the top 10 centimeters may not be solidified. In the treatment of Bailey Bay, the Japanese suggested that an area be inclosed and the water within the area be pumped out. Then the bottom sediments can be solified to the surface.

The Japanese stated that they can develop a solidifier that will be effective in resolving the Kepone problem in Bailey Bay. However the laboratory requires an additional 70 gallons of sludge with Kepone thereon from Bailey Bay in order to run further tests for the design of a solidifier. In the past, the laboratory has had problems pertinent to the design of various additives. However when they were used in the field, the progress was satisfactoy. This was evident on the projects that the team visited. The Takenaka technicians stated that no salt would leach out of the sludge in Bailey Bay after it had been stabilized.

The necessary hardener equipment, which Takenaka would have to bring to the United States, depends on the amount of surface to be solidified. The company does have a small solidification machine which can be hung from a crane. The team did not see this equipment. It would take 6 months to mobilize the equipment for this project. Portland cement would be obtained from the nearest distributor. The TB additive would probably be manufactured in Chicago.


N
LIFE SCIENCE
CITY POINT
CHARLES CITY CO.
ALLIED CHEMICAL CO.
JAMES RIVER
CHESTERFIELD CO.
APPOMATTOX RIVER
HOPEWELL
BAILEY BAY
GRAVELLY RUN
GRAVELLY RUN
CREEK
RT. 10
BAILEY CREEK
FORT LEE
BAILEY
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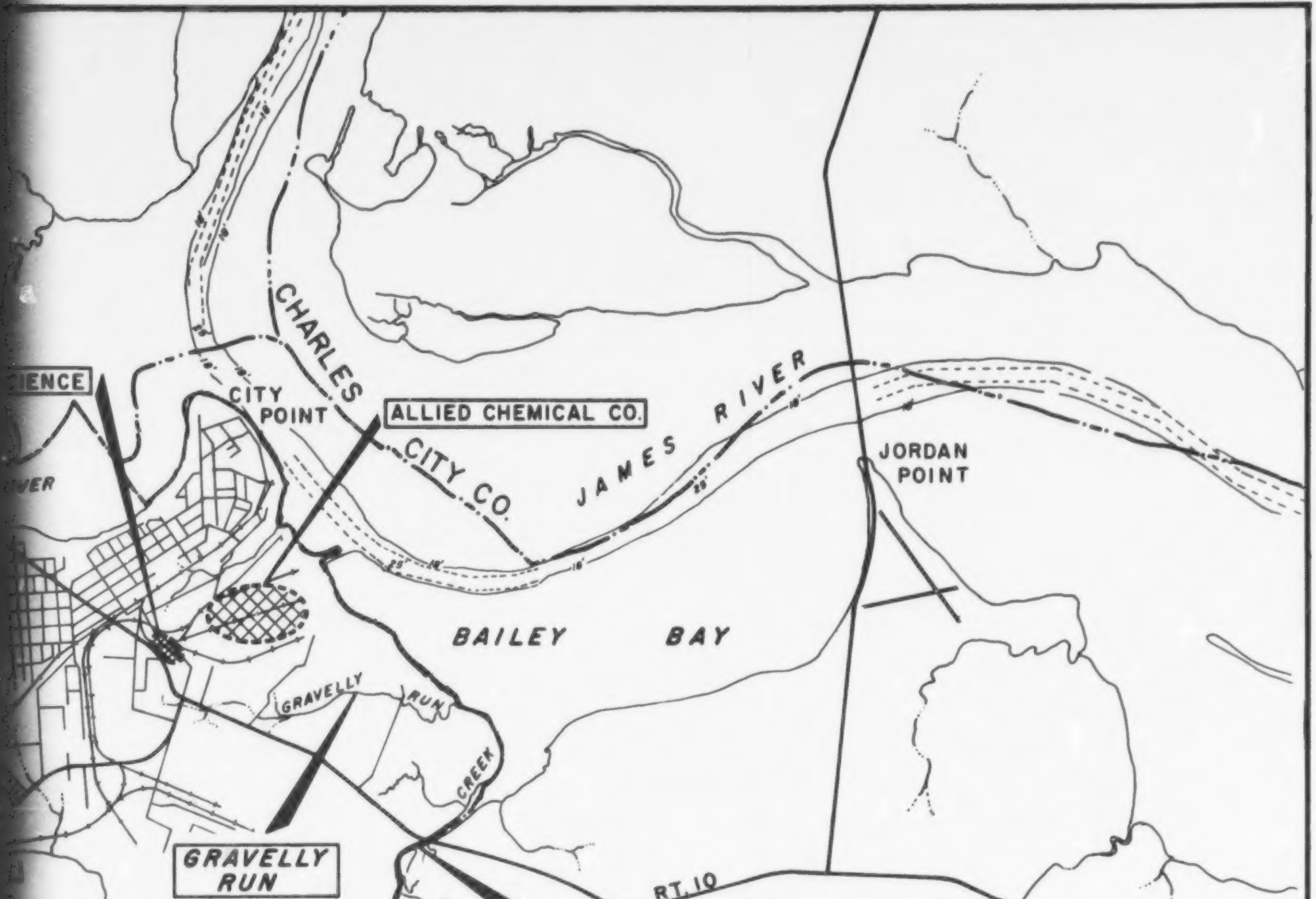
SEWAGE TREATMENT PLANT
SCALE IN FEET
2000 0 2000 4000
RT. 156

A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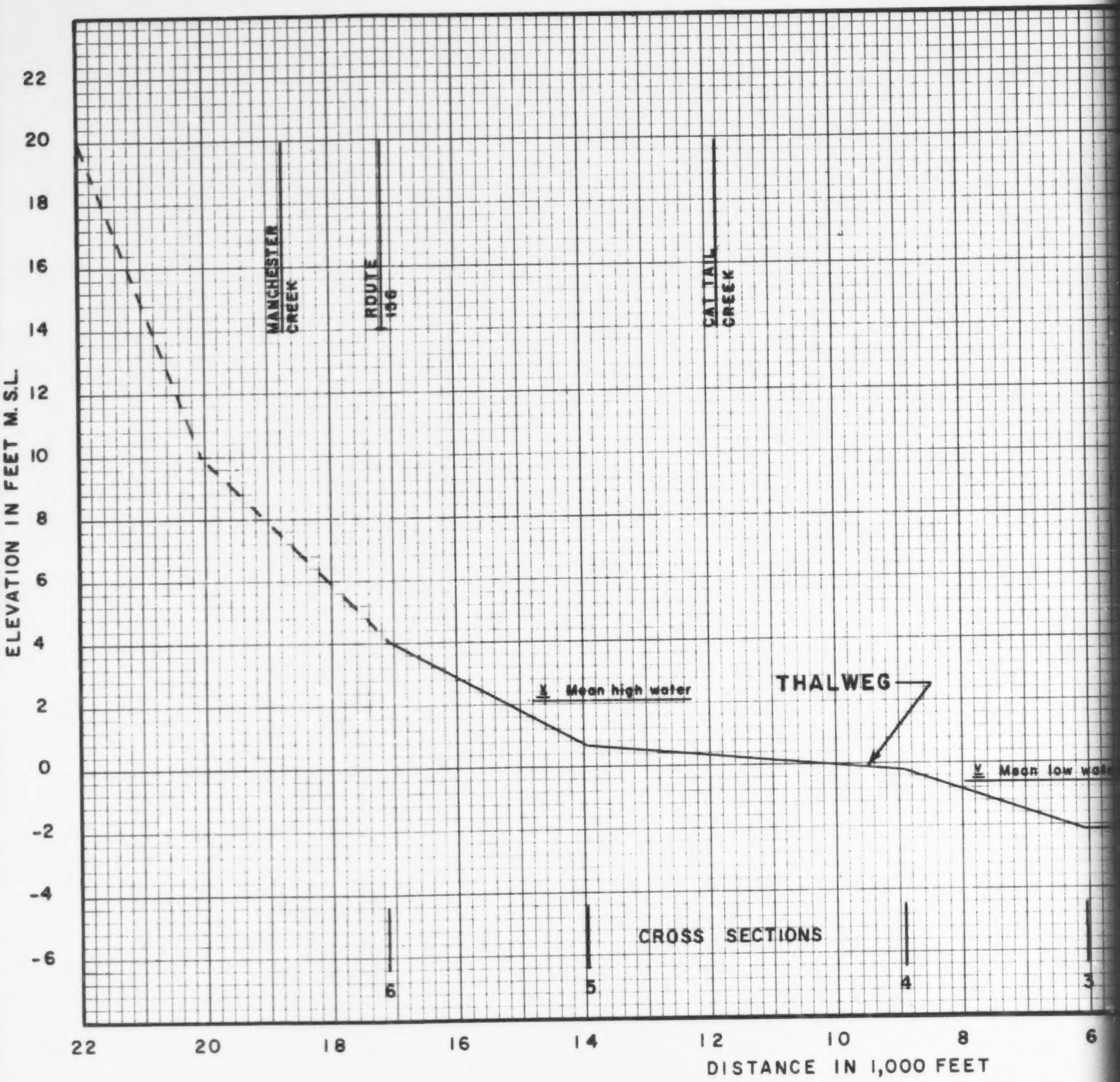
BAILEY CREEK
RT. 10
BAILEY
PRINCE GEORGE CO.
SEWAGE TREATMENT PLANT
SCALE IN FEET
2000 0 2000 4000
RT. 156

HOPEWELL, VIRGINIA
KEPONE STUDY
STUDY AREA
NORFOLK DISTRICT
CORPS OF ENGINEERS
SEPTEMBER 1977

B

PLATE A-1


22
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ELEVATION IN FEET M. S.L.
MANCHESTER CREEK
ROUTE 156
CAT TAIL CREEK
Mean high water
THALWEG
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DISTANCE IN 1,000 FEET

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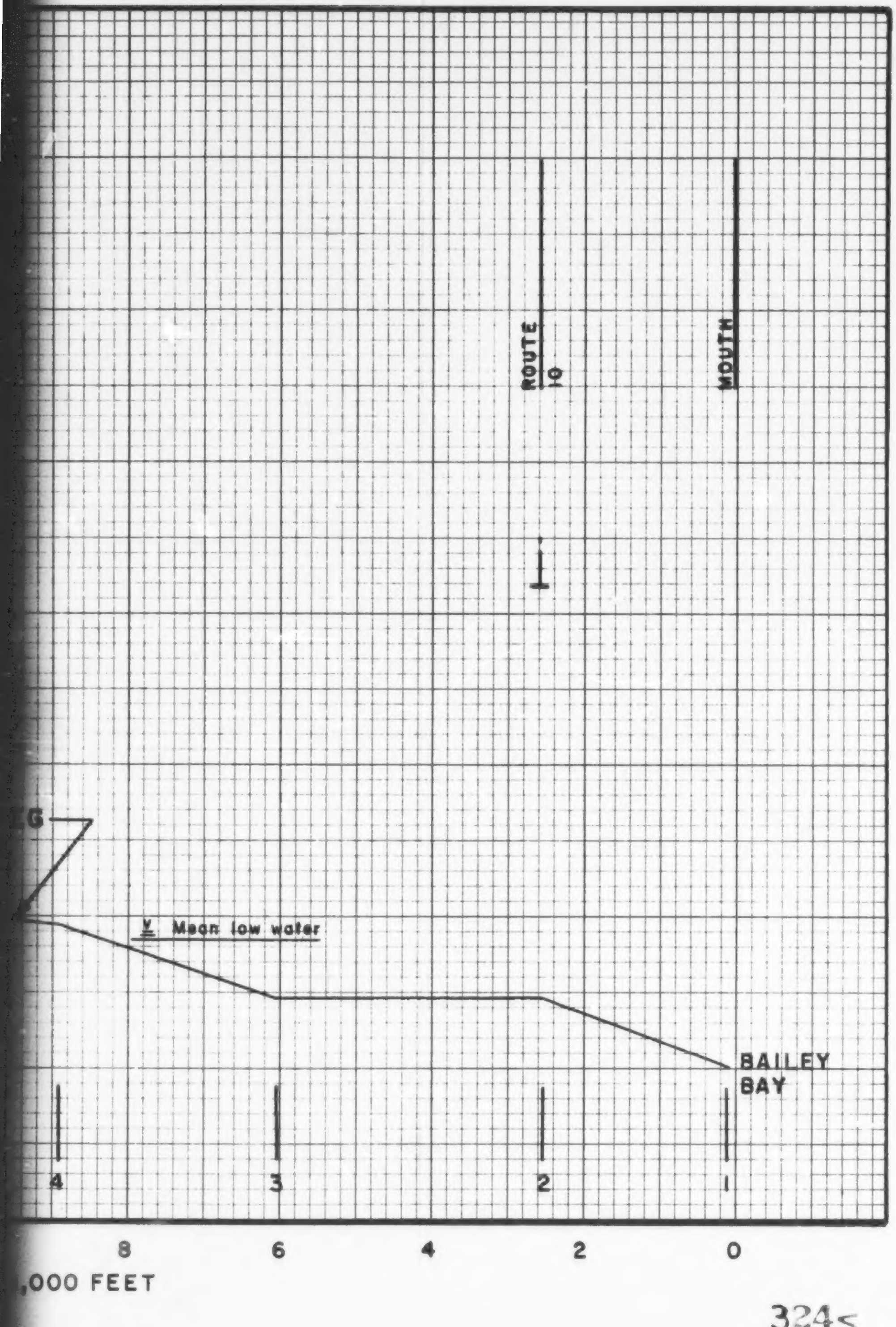


LEGEND:

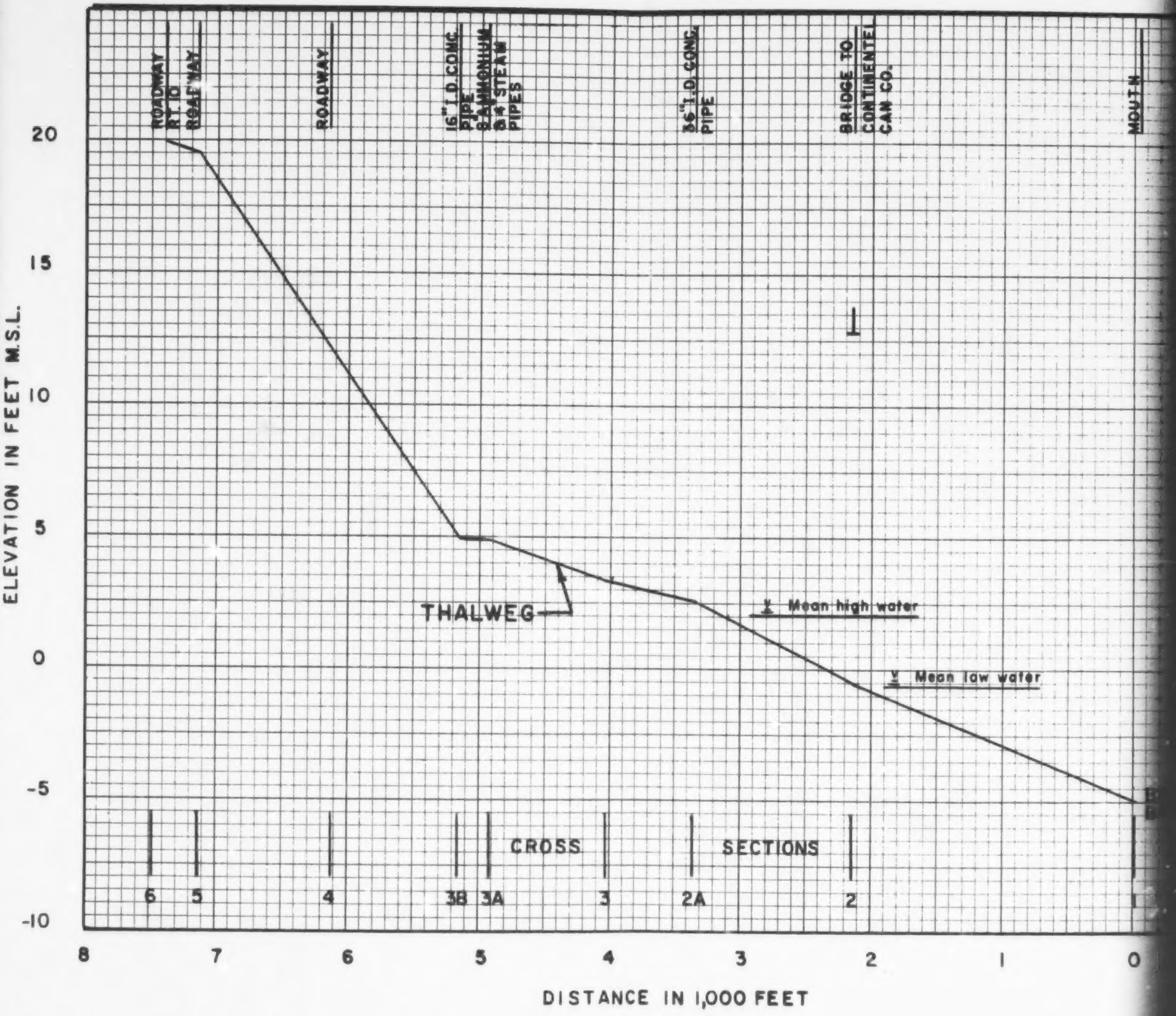
⊥ LOW STEEL

HOPEWELL, VIRGINIA
KEPONE STUDY
PROFILE
BAILEY CREEK
NORFOLK DISTRICT
CORPS OF ENGINEERS
JULY 1977

324<

B

PLATE A-2


ROADWAY
RT. 10
ROADWAY
ROADWAY
16" I.D. CONC. PIPE
8 AMMONIUM
& 4 STEAM
PIPES
36" I.D. CONC. PIPE
BRIDGE TO CONTINENTAL CAN CO.
MOUTH
THALWEG
Mean high water
Mean low water
CROSS SECTIONS
6
5
4
3B
3A
3
2A
2
1
ELEVATION IN FEET M.S.L.
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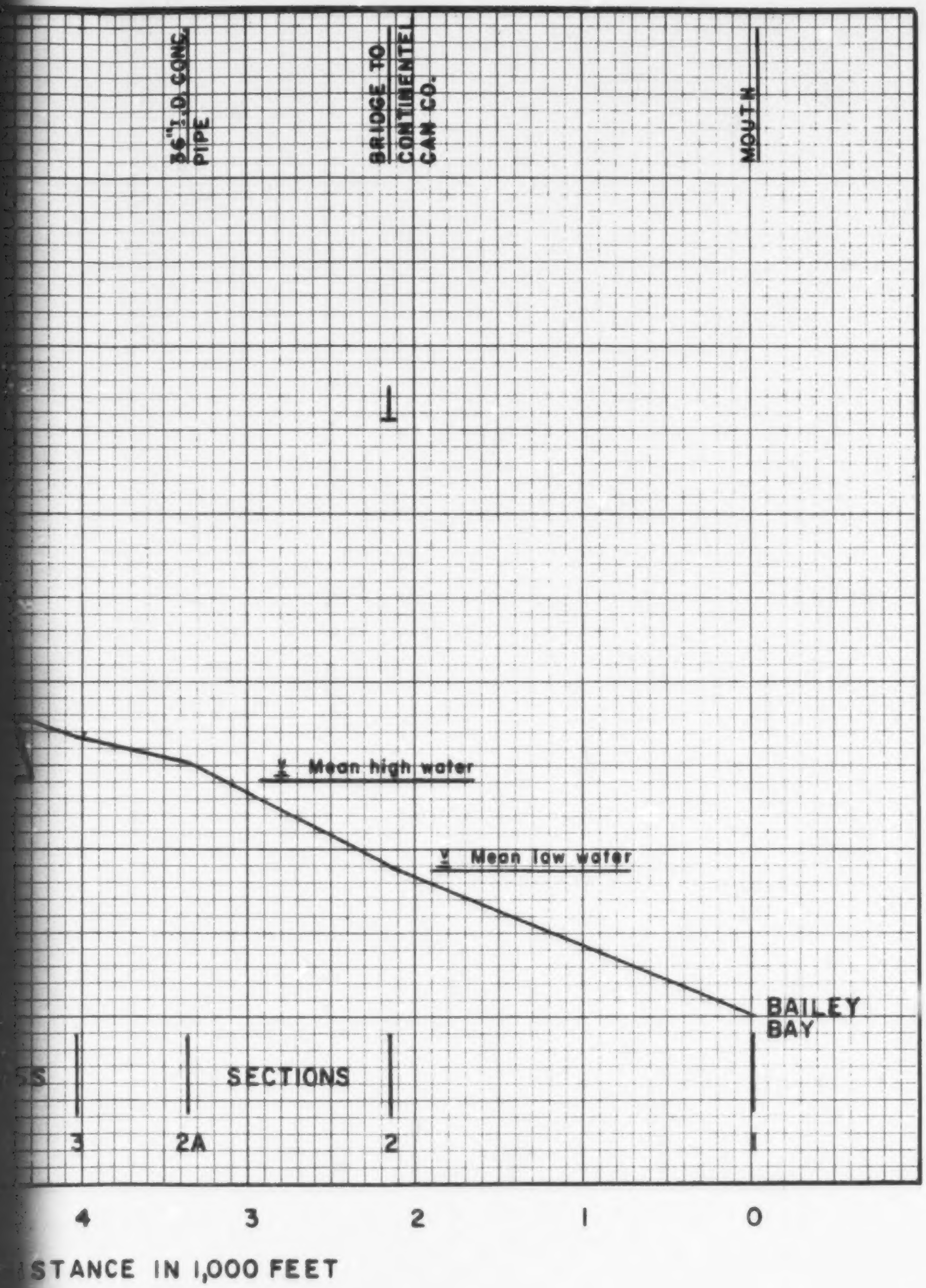
DISTANCE IN 1,000 FEET

A



LEGEND:

⊥ LOW STEEL

HOPEWELL, VIRGINIA
KEPONE STUDY
PROFILE
GRAVELLY RUN
NORFOLK DISTRICT
CORPS OF ENGINEERS
JULY 1977

325<

PLATE A-3

SECTION B

ENVIRONMENTAL ASSESSMENT OF ENGINEERING ALTERNATIVES FOR CAPTURING,STABILIZING,OR REMOVING KEPONE FROM BAILEY BAY, BAILEY CREEK,AND GRAVELLY RUN, CITY OF HOPEWELL AND PRINCE GEORGE COUNTY,VIRGINIA

SECTION B

ENVIRONMENTAL ASSESSMENT OF ENGINEERING ALTERNATIVES FOR CAPTURING, STABILIZING, OR REMOVING KEPONE FROM BAILEY BAY, BAILEY CREEK, AND GRAVELLY RUN IN HOPEWELL AND PRINCE GEORGE COUNTY, VIRGINIA

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INTRODUCTION

In July 1975, Kepone, a chlorinated hydrocarbon insecticide used in the manufacture of ant and roach poison, was found in the bloodstreams of workers at the Life Science Products Company plant in Hopewell, Virginia. The Life Science Products Company was manufacturing Kepone under agreement with the Allied Chemical Company, also located in Hopewell. Subsequent analysis of environmental samples obtained by the Health Effects Research Laboratory of the U.S. Environmental Protection Agency (HERL, 1975) indicated that Kepone was widely distributed in the vicinity of the Life Science Products Company plant and in the sediments and biota of the James River on which the city of Hopewell is located (see plate B-1). Later sampling by the U.S. Army Corps of Engineers, the Virginia State Water Control Board, and the Virginia Institute of Marine Sciences confirmed this and suggested that several "hot spots" or areas of unusually high concentrations of Kepone existed in the sediments of Gravelly Run, Bailey Creek, and Bailey Bay (plate B-2) and to some extent in Tar Bay and at the mouth of the Chickahominy River, all on the James River.

In light of these findings, the Environmental Protection Agency requested the Corps of Engineers to investigate possible engineering alternatives "for capturing, stabilizing, or removing Kepone in Bailey's Bay (sic), Bailey's Creek (sic), and Gravelly Run...," under authority discussed in the following section.

AUTHORITY

The study of the engineering alternatives was conducted under Interagency Agreement No. EPA-IAG-D7-01074 between the Environmental Protection Agency and the U.S. Army Corps of Engineers. Specific authority for the interagency agreement is cited as the Economy Act of 1932, as amended (31 USC 686); section 115 of the Federal Water Pollution Control Act (Public Law 92-500); and the River and Harbor Act of 1965, as amended (Public Law 89-299).

ENVIRONMENTAL INVENTORY

The project area defined for the study of the environmental effects of the proposed actions included the drainage areas of Bailey Creek, Gravelly Run, and the area of Bailey Bay inclosed by the shoreline from Jordan Point to City Point, and the southern boundary of the Federal navigation channel in the James River (see plate B-2). Included in this area are two major political subdivisions: the city of Hopewell and Prince George County.

BRIEF HISTORY OF THE PROJECT AREA

The first settlement in the Hopewell-Prince George County area occurred in 1613 at City Point where the Appomattox River flows into the James River. It was called Charles City. After the town was destroyed in 1622 by the Indians, it was rebuilt and called Charles City Point. In 1635 Francis Eppes received a grant from King Charles for much of the land at the point, including the town site. His home, Appomattox Manor, which he built on this land, is still owned by descendants and it is on the National Register of Historic Places. In 1702 Prince George County was formed from Charles City County, and the village name was changed to City Point.

During the Revolutionary War, Benedict Arnold shelled Appomattox Manor in a waterborne assault on the area. The Civil War brought further military action here from June 1864 to April 1865. General Grant set up his headquarters in Appomattox Manor in 1864 and commanded the Union armies in the South and West from this location. President Lincoln and Vice President Johnson also visited City Point during the final stages of the war.

In addition to Appomattox Manor in Hopewell, the following properties in Charles City County are listed on the National Register of Historic Places: Eppes Island, located at the confluence of the James and Appomattox Rivers and Shirley Plantation, located 5 miles north of Hopewell. Other National Register properties in Charles City County, Hopewell, and Prince George County are well beyond the study area.

From an area of about 300 people, Hopewell developed into a boom town, similar to those in the West, after the completion of a dynamite plant in 1913 by the DuPont de Nemours Company. DuPont built its plant on a portion of 1,800 acres of land purchased from the Appomattox Manor estate. With the beginning of World War I, the factory was converted for the production of gun cotton and was making more than 1,000,000 pounds a day until the end of the war. The population of Hopewell was estimated to be approximately 40,000 during this period, with 15,000 to 20,000 people working at the factory. In 1916 Hopewell was incorporated as a city.

With the end of World War I and the closing of the DuPont factory, people left Hopewell as rapidly as they had come. By 1920 the census showed a city population of only 1,320. During the next decade, however, the population began to increase again as new industries moved to the area formerly occupied by DuPont's gun cotton plant.

The first company to locate here after World War I was the Samsocott Company, which began production of cellulose products in 1920. This company was taken over by the Virginia Cellulose Company in 1923 and 3 years later by the Hercules Powder Company. Its principal product was a substance used to make explosives, but it also manufactured film, lacquers, and raw material for rayon, transparent cellulose, and stationery. Today the Hercules Powder Company employs over 1,000 people making plastic materials, synthetic resins, and alkaline and chlorine industrial inorganic chemicals.

One of the largest companies to begin operation in this decade was the Tubize Artificial Silk Company, which bought over 250 acres and built homes for about 500 of the 3,000 employees. This company eventually went out of business as did the Hopewell China Company and the Hopewell Trunk and Bag Company, both of which were established in the 1920's.

The Hummel-Ross Fibre Corporation bought 150 acres for a plant to produce kraft paper and boxboard. The wood from approximately 20 acres of forest was used to produce 45 tons of sulphate liner and 40 tons of wrapping paper daily. In 1949 the Continental Can Company purchased its Hopewell plant from Hummel-Ross Fibre Corporation. Today Continental Can produces liner board and a corrugating medium used in the manufacture of corrugated boxes.

In 1928 Allied Chemical and Dye Corporation spent millions of dollars to set up a nitrate plant through their subsidiary, the Atmospheric Nitrogen Corporation. Later, in 1954, the National Aniline Division of Allied Chemical located a fiber operation along Route 10 next to the nitrogen plant. This plant produced the raw materials for the manufacture of fibers which were sent to a site at Bermuda Hundred in

Chesterfield County for final processing. In addition to these factories, the General Chemical Division of Allied Chemical built a small plant near Route 10. In 1960 the Aniline Division expanded in order to triple the production of nylon tire cord and start producing nylon yarn. However, most of the expansion occurred at the Chesterfield County yarn plant. Currently, Allied Chemical maintains two plants in Hopewell, the Plastics Division and the Industrial Chemicals Division. Plastics Division, established in 1973 by the merger of the plastics and agriculture plants, produces industrial inorganic chemicals. The Industrial Chemicals Division (I.C.D.) manufactures alum. Together, these two plants employ approximately 800 people.

Firestone is still another industry which found Hopewell an excellent industrial site. Located in the city in 1960, Firestone is a major producer of nylon and polyester yarns. With about 1,500 employees, this company is the largest industrial employer in Hopewell.

SOCIAL BACKGROUND

The populations of both Hopewell and Prince George County have increased since 1950 as seen in the following U.S. Census data:

	1950	1960	1970
Hopewell	10,219	17,895	23,471
Prince George County	19,679	20,270	29,092

However, several annexations have occurred in the past 25 years which affect the above figures. When the 1960 and 1970 counts are adjusted for the annexations occurring through 1972, these figures result:

	1960	1970
Hopewell	18,770	23,471
Prince George County	19,395	24,371

The most recent estimates indicate that Hopewell has a population of 23,300 and Prince George County has a population of 18,700 as of 1 July 1975 (University of Virginia, 1975). In addition to the annexations, Prince George County's population has fluctuated because of the changes in troop levels at Fort Lee. In 1970 Fort Lee's population was 12,435, a large portion of the county figure of 29,092.

The composition of Hopewell's population by age groups closely parallels the State averages, according to census data, with median age for the city 26.0 and 26.8 for Virginia as a whole. Because of the Fort Lee population, the median age for the county was 22.3, somewhat below the State average. The breakdown by sex also shows similar patterns between Hopewell and the State. Hopewell had slightly more women than men, while the county had 18,753 men and 10,339 women.

Projections for the area's population through the year 2000 show small but steady increases for both Hopewell and Prince George County, as can be seen in the following figures (Virginia Department of Planning and Budgeting):

	1970	1980	1985	1990	1995	2000
Hopewell	23,471	25,000	25,800	26,600	27,200	27,700
Prince George County	29,092	23,000	25,100	27,200	29,300	31,500

The projections of Prince George County estimate considerably more growth for the county than the State projections indicate. In 1980 population is predicted to be 27,300, 31,100 in 1985, and 35,000 in 1990. County personnel predict that the county will grow as a result of more people moving from Petersburg and Hopewell and increased employment opportunities in the area (Prince George County, 1976).

However, these projections may be too high when the long-range (20-year) plans of Fort Lee are considered. The master plan of Fort Lee estimates a 4 percent reduction in overall personnel employed and stationed at the base and a much larger decrease in the number of military personnel permanently stationed there (as opposed to TDY personnel) as well as civilians working there.

The housing picture in this area shows somewhat mixed conditions (see table B-1). The 1970 home and rent values show Prince George County with fewer houses in the lower price ranges compared to Hopewell, but with levels roughly comparable to the State averages. The rent figures for Hopewell show them to be lower than those for Virginia; those for the county are skewed because of the presence of Fort Lee.

Table B-1. VALUE AND CONTRACT RENT OF HOMES (1970)[1/]

	Hopewell	Prince George County	Virginia
Value: Specified Owner Occupied			
Less than $ 5,000	2.4%	6.1%	6.7%
$ 5,000 to $ 9,999	21.6	12.1	14.8
$10,000 to $14,999	31.1	18.0	19.7
$15,000 to $19,999	24.6	27.4	18.7
$20,000 to $24,999	10.0	18.8	13.1
$25,000 to $34,999	7.4	13.4	14.4
$35,000 or more	2.9	4.2	12.7
TOTAL	100.0%	100.0%	100.0%
Monthly Contract Rent: Specified Renter Occupied			
Less than $ 40	7.5%	6.3%	9.7%
$ 40 to $ 59	14.7	3.2	13.7
$ 60 to $ 79	23.7	4.6	14.8
$ 80 to $ 99	21.6	5.2	11.8
$100 to $149	26.4	31.0	25.3
$150 or more	4.0	4.0	17.1
No cash rent	2.2	45.7	7.6
TOTAL	100.0%	100.0%	100.0%

[1/] U.S. Bureau of the Census

In 1970 the housing in the county was slightly more overcrowded and had more overcrowded units than Hopewell's homes, but it was still comparable to the regional average (Petersburg, Colonial Heights, and Hopewell SMSA) for these parameters. One significant difference between the city and county was the percentage of mobile homes in Prince George County--18.4 percent compared to 2.0 percent for Hopewell and 4 percent for the region. The shift from single-family to mobile homes in the county started in the 1960's and may be related to the large increase in housing costs which put the median home value for the county above that for the region as a whole.

As would be expected, Prince George County's population is much more transient than Hopewell's because of the military presence there. In 1970 only 28 percent of the county residents were living in the same house as they had been 5 years earlier compared to 51 percent in Hopewell and 50 percent Statewide. Correspondingly smaller percentages of county residents in 1970 were living in the same county or state in 1965 than in Hopewell or the State.

Commuter patterns for 1970 show that the in and out commuting to Hopewell tended to balance out, whereas Prince George had almost 2,000 more in-commuters. However, since 1970 the county's importance as an employment center has decreased. Because of Petersburg's annexation in 1972, the county lost the Prince George Industrial Park and the major retail facilities along Route 301.

Manufacturing is the foundation of Hopewell's economy, and it directly provides slightly over 50 percent of the city's jobs. Allied Chemical Corporation, Hercules Powder Company, Firestone Synthetic Fibre Company, and Continental Can Company are the major employers in this area. Additional jobs are found in wholesale and retail trade and in government. By contrast, in Prince George County governmental agencies, primarily Federal, account for two-thirds of the employment as of 1972. This percentage should decrease since civilian employment by the military for the region is expected to fall by 21 percent between 1970 and 1980. On the other hand, regional manufacturing employment is expected to increase 33 percent during the same period (Virginia Department of Planning and Budgeting).

Income levels for both Hopewell and Prince George County are close to State levels as can be seen in the following table:

Table B-2. DISTRIBUTION OF FAMILIES BY 1969 INCOME[1]

Annual Income Interval	Percent of Hopewell total	Percent of Prince George County total	Percent of State total
$ 0 - $ 999	2.2	2.2	2.8
$ 1,000 - $ 3,999	10.6	9.3	13.4
$ 4,000 - $ 7,999	26.7	32.3	26.4
$ 8,000 - $11,999	31.0	28.2	25.3
$12,000 - $14,999	13.1	13.8	12.2
$15,000 - $24,999	14.6	11.8	15.2
$25,000 - $49,999	1.4	2.4	4.0
$50,000 or more	0.4	0.0	0.6
TOTAL	100.0	100.0	100.0
MEDIAN	$9,200	$8,776	$9,049

[1] U.S. Bureau of the Census

LAND-USE PATTERNS AND PLANS

The city of Hopewell occupies an area of approximately 11 square miles or 7,013 acres. According to the Land-Use Plan for Hopewell, Virginia, 56 percent of the land area in 1970 was developed, the majority being in the residential and industrial categories (see table B-3).

Table B-3. EXISTING LAND-USE COMPARISON WITH SIMILAR SIZE CITIES

	Hopewell 1/				Similar Size Cities 2/		
Land use category	Acres used	Percent of city area	Percent of developed area	Acres 100/ population	Acres developed	Percent development	Acres 100/ population
Residential	1,762	25.1	44.6	7.80	1,143	41.9	5.12
Commercial	161	2.2	4.0	.71	96	3.5	.43
Industrial	1,266	18.0	32.0	5.61	295	10.8	1.33
Public & semipublic	173	2.4	4.3	.76	492	18.0	2.21
Roads & streets	583	8.3	14.7	2.58	703	25.8	3.15
Total developed area	3,944	56.2	100.0	17.47	2,730	100.0	12.23
Vacant, agriculture & Forest	2,815	40.1					
Water area	254						
TOTAL	7,013	100.0					

1/ Source: Computer printouts, Hopewell Thoroughfare Plan, 1970. Revised to include annexed area of Prince George County with city of Hopewell.

2/ Source: Land Use in American Cities, Harland Bartholomew, Revised 1969.

Compared to other cities of the same size, Hopewell has a far greater percentage of land devoted to industry but less devoted to public and semipublic uses, including roads and streets. The major deficiency is the lack of park and recreation space. Residential acreage per person has been following the national trend, and although substantially larger than similar size cities, Hopewell should maintain a relatively high ratio for the immediate future. Low density and larger lot developments, together with the current tendency to smaller family size, helped to increase this ratio. The city can expect continued extensive use of land for residential purposes as long as these conditions continue.

Probably the single greatest factor influencing the land-use pattern is the large industrial complex composed of Allied Chemical Company, Firestone, Hercules Powder, and Continental Can Company adjacent to the Poythress Run, the James River, and Route 10. The nature and character of the industry dominates other types of development and has forced development westerly away from the James River. In recent years the greatest amount of population growth has occurred in the western portion of the city toward the boundary of Fort Lee, and it is anticipated that this trend will continue.

Future growth in the Hopewell area is expected to take place primarily south and west of the existing city. Most of this land is suitable for development in terms of its physical characteristics, such as slope. Undeveloped areas adjacent to the James River southeast of the city have been subject to pressure for industrial growth, although much of the present industrial land is open space and can be utilized for necessary expansion in the future.

The section of the city bordering Bailey Creek on the western side is currently zoned for heavy industry to a point just past the old sewage treatment plant and for housing (residential) from that point on. Although much of this area zoned residential is vacant, housing construction is currently taking place between the sewage treatment plant and Route 156. The creek bank and the adjacent flood plain have been designated a conservation area for future use, and no construction should take place in this area. However, further residential development may occur in areas near the creek, particularly those for which "paper" streets exist.

Prince George County's total land area is about 276 square miles or 170,640 acres. The dominant characteristic of the land use is the forest and farmland, which take up 94 percent of the total area. Almost three-fourths of the county is in forest land, either for commercial use or as woodlands or farms; 20 percent is farmland other than forest; and the remaining 5 percent is devoted to residential, commercial, industrial, or public use. Much of this forest land exists in large sections of over 400 acres owned by a relatively small number of people. Continental Can Company, Inc., which is the largest single owner, has almost 28,000 acres, or 16 percent of the county. Most of the existing residential development is concentrated near Petersburg and Hopewell and along the main transportation routes. Commercial establishments are generally scattered throughout the county, and industries are found mostly in the section of the county north of Fort Lee. Public recreation acreage, which is limited to land adjacent to public school sites, is considered insufficient for county residents.

The existing zoning for the county has most of the land (87 percent) zoned agricultural. Table B-4 shows the breakdown by the seven land-use categories. Much of the land zoned residential is not developed. In fact, if this land was developed at its lowest density of residential use, it would have a population capacity of nearly 67,000 people, a condition not expected until well into the next century.

Table B-4. NUMBER OF ACRES, BY ZONING CATEGORY

Category	Acres	Percent Distribution
Residential		
R-1	6,725	3.8
R-2	2,890	1.7
R-3	210	0.1
Subtotal	(9,825)	(5.6)
Business		
B-1	1,550	0.9
Industrial		
M-1	270	0.1
M-2	3,120	1.8
Subtotal	(3,390)	(1.9)
Agricultural		
A-1	152,930	87.2
Federal Land[1]	7,675	4.4
TOTAL ACRES (COUNTY)	175,360	100.0%

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[1] Fort Lee and Petersburg National Battlefield Park

NOTE: These figures are estimated from the Prince George County Zoning Map and are, therefore, approximate.

Current land-use plans aim at concentrating new residential growth in the most populous part of the county near Hopewell and Petersburg and in the existing small communities throughout the rest of the county. The service areas for water and sewerage facilities will be the primary influence over future growth patterns in the more developed part of the county. Public water services will encourage the location of subdivisions and multifamily housing projects, commercial activities, and industrial uses in the more suburban parts of the county. For the rest of the county, retention of agricultural and timber land, especially that which is 20 years old and older, is being emphasized with residential development of low density and large lots being permitted. Both the James and the Appomattox Rivers have the potential to be significant centers for water-oriented recreation activities.

The county land areas adjacent to Bailey Creek are planned primarily for residential development through the year 2000. The creek itself, its tributaries, and their banks have been proposed as critical environmental areas where no construction will take place. Plate B-3 shows the projected future land use for most of the county area that lies in the Bailey Creek drainage area. (Most of this area is currently undeveloped forest.) While this area currently has a population of 1,928, the capacity under the proposed plan would be 14,214 people, which would more than cover the projected increases for the next two decades.

Area 1 covers 1,500 acres and includes a housing area and a shopping center. Plans show 25 acres of commercial land use, most of which will be at the intersection of Routes 156 and 646, and 260 acres for residential purposes (see plate B-4 and table B-5).

Area 2 is mostly undeveloped at present with much of the existing population of 496 centered in the southwest corner. Most of the 3,000 acres are scheduled to remain undeveloped with 515 acres for residential uses, 14 acres for industry, and 5 acres for public use.

The largest section, Area 3, has 4,820 acres and one major residential development. Water and sewer lines, which will encourage residential construction, have been proposed for several sections of this area. In addition to the 800 acres planned for residential zoning, 18 acres will be for commercial structures, and 2 recreation centers will be needed for the increased population (Prince George County, 1976).

Table B-5. PROPOSED LAND USES FOR YEAR 2000 IN ACRES

Land Use	Area 1	Area 2	Area 3	Total
Residential	260	515	800	1,575
Multifamily (8 units/acre)	17	50	17	84
4 units/acre	101	200	402	703
2 units/acre	60	170	241	471
1/2 unit/acre	82	95	140	317
Commercial	25	0	18	43
Industrial	0	14	0	14
Public Use	0	5	5	10

TOPOGRAPHY AND GEOLOGY OF THE PROJECT AREA

Relief in the project area runs approximately 5 feet below mean low water (m.l.w.) to 150 feet above m.l.w. at the edge of the project area. Most of the abrupt changes in topography occur on the several branches of Bailey Creek located in Prince George County. Slopes in the county portion of the project area can approach 40 to 50 percent in some of the steeper areas of these tributaries. In the city of Hopewell and Fort Lee sections of the project area, slopes are more gradual and amenable to the development that has occurred at these sites.

Both Hopewell and Prince George County lie along the western limits of the Coastal Plain province and are underlain with sand, gravel, clay, and marl. Sediments in the county are relatively thin in the western part and gradually thicken to about 500 feet along the James River at Brandon. At Hopewell the bedrock lies between 300 and 500 feet below the surface of the land. Much of the soil in this whole area has been formed from rock fragments washed down from the Piedmont.

Numerous aquifers in the sediments furnish moderate to large supplies of ground water. Depths vary from 100 to 300 feet with the majority producing between .25 and 2.0 gallons per minute per foot of drawdown. The chemical quality of the ground water from the Coastal Plain sediments is usually hard, acidic, and contains slight amounts of iron. The water from deeper wells produced from the bedrock fractures is usually softer and more desirable.

ARCHEOLOGICAL RESOURCES

At present, little is known concerning the archeological resources of the project area, although at least five upland archeological sites have been identified by the Virginia Historic Landmarks Commission (see plate B-5).

AIR QUALITY IN THE HOPEWELL-PRINCE GEORGE AREA

Two air quality parameters are regularly measured in the project area by the Virginia State Air Pollution Control Board (SAPCB). These two parameters are suspended particulates and sulfur dioxide.

For the year ending March 1977, sulfur dioxide (SO_2) did not appear to be a problem according to SAPCB measurements (see table B-6). No violations of the National Ambient Air Quality Standard's (NAAQS) secondary standard of 0.14 parts per million SO_2 were noted either at the Hopewell News Building or the Hopewell Airport.

Three violations of the NAAQS for suspended particulates were noted at the Hopewell News Building during the April 1976 to March 1977 time period. These three violations were caused by the concentration of suspended particulate matter exceeding the NAAQS secondary standard of 150 micrograms of suspended particulates per cubic meter.

Table B-6. AIR QUALITY DATA FOR THE KEPONE STUDY PROJECT AREA, APRIL 1976 TO MARCH 1977 [1]

Location	Suspended particulates				SO_2		
	Time period	Geometric Mean	N[2]	>150 mg/m^3	Arithmetic Mean	N[2]	>0.14 ppm
Hopewell News Building	Apr-Jun 76	79 mg/m^3	15	0	0.01 ppm	15	0
	Jul-Sep 76	86	15	1	0.01	14	0
	Oct-Dec 76	59	15	2	0.01	14	0
	Jan-Mar 77	64	14	0	0.01	13	0
Hopewell Airport	Apr-Jun 76	42	15	0	<0.01	15	0
	Jul-Sep 76	39	15	0	<0.01	15	0
	Oct-Dec 76	29	15	0	0.01	14	0
	Jan-Mar 77	31	15	0	0.01	14	0

[1] Source: Virginia Air. State Air Pollution Control Board.
[2] N = Number of observations.

Odor is also a problem in the project area. Odor-causing substances are emitted from the several fiber mills in the area. Also the emission of similar odors from Bailey Creek and Bailey Bay "black" water was noted on several trips to this area by boat. It is expected that the odor problem will abate substantially when the Regional Sewage Treatment Plant begins operation later this year (1977). No measurements were made in the project area for carbon monoxide, photochemical oxidants, hydrocarbons, or nitrogen oxides. Recent research on the atmospheric movement of hydrophobic chlorohydrocarbons from natural water bodies (Singmaster and Crosby, 1977) indicates that these substances can evaporate into the atmosphere from water bodies. Even though the solubility of these compounds is low, the report suggests that these compounds are rapidly transferred to the atmosphere after they are dissolved from the sediments. If this process occurs in the Bailey Creek - Bailey Bay area, the agitation from wind driven waves may introduce these substances into the atmosphere and adversely affect ambient air quality in the Hopewell area.

WATER QUALITY IN THE PROJECT AREA

Water quality in Bailey Creek can generally be described as poor. Water quality data for two sampling sites in Bailey Creek were compared with two stations located in the James River near the project area. Some of these data are summarized in the following table.

Table B-7. SUMMARY OF WATER QUALITY DATA FOR BAILEY CREEK JANUARY 1974 to DECEMBER 1976 AND THE JAMES RIVER JUNE 1974 to JUNE 1976 (VASWCB STORETS DATA)

Location	Water Temp (°C)	DO mg/1	ph	5-day BOD mg/1	TKN mg/1	NO -N mg/1	Ortho Phos mg/1
Upper Bailey Cr	63.0(17.2)	5.7	6.5	57.5	8.6	0.28	2.24
Lower Bailey Cr	66.2(19.2)	2.1	8.5	190	9.6	1.57	0.94
James River	72.4(22.6)	7.5	7.4	2.4	0.57	0.42	0.04

NOTE: The above values are the averages of Virginia State Water Control Board data determined in samples from the indicated locations.
1/ Some winter data points omitted.

These data support the conclusion that the water quality in Bailey Creek is "poor". The decreased dissoved oxygen (DO) average and increased pH average in going from the upper Bailey Creek to the lower reach further supports this conclusion. Levels of BOD, TKN, (total Kjeldahl nitrogen) and nitrate-nitrogen are significantly higher in Bailey Creek than in the James River at the station referenced (north side of the channel near Hamson Point). While the nutrient, BOD, and pH levels have increased between the upper and lower station, the orthophosporus level has decreased substantially. This decrease is probably due to the rapid uptake of this nutrient by the stream's biological system, which is apparently mostly bacteria and algae.

Bailey Creek is a tidal estuary with significant inflow of freshwater from the drainage area and, during periods of low runoff, from the sewage treatment facilities located along its course. Several of these outfalls originate from the Hercules Powder Company and the Fort Lee Military Reservation at the headwaters of the creek. Under normal conditions these effluents are given primary treatment before discharge.

The State Water Control Board (SWCB) does not have monitoring stations on Gravelly Run; so the description of its water quality is difficult. Aerial imagery done by the NASA-Langley Research Center shows that the effluent from Gravelly Run is of high temperature. This was seen in a reading of 32°C (89.6°F) taken on 13 May 1976 at a time when the temperature in Bailey Bay ranged from 24.5°C to 26°C. The high temperature of the water in Gravelly Run is due to the disposal of heated process water from the Allied Chemical and Continental Can Company facilities situated on Gravelly Run. On the same day, the conductivity of Gravelly Run was measured at 400 micromhos. This was significantly less than the 2,900 micromhos measured at the mouth of Bailey Creek, but several times greater than the 150 to 175 micromhos measured over a 7.5-hour period on the James River on 17 May 1977 just downstream of Jordan Point near buoy 102.

Bailey Bay is an area of variable water quality due to the influences of the current flows and tides from the James River and runoff of rainfall and effluents from Bailey Creek, Gravelly Run, and Continental Can Company. The effluents from Bailey Creek and Continental Can Company stain the water of Bailey Bay a dark brown to black. This color is readily visible from both the ground and the air. The current pattern in Bailey Bay carries the stained waters along the shore of the bay and around Jordan Point into Tar Bay during most of the tidal cycle. During portions of the flood tide, the current pattern causes some transport of the dark water from Bailey Bay into the lower reach of the Appomattox River which is located just west of City Point (Whitlock and Tallay, 1977). The black material has been assumed to be lignins from the "fiber" operations in Hopewell, although this has not yet been supported by actual analysis for these substances (see figure B-1),

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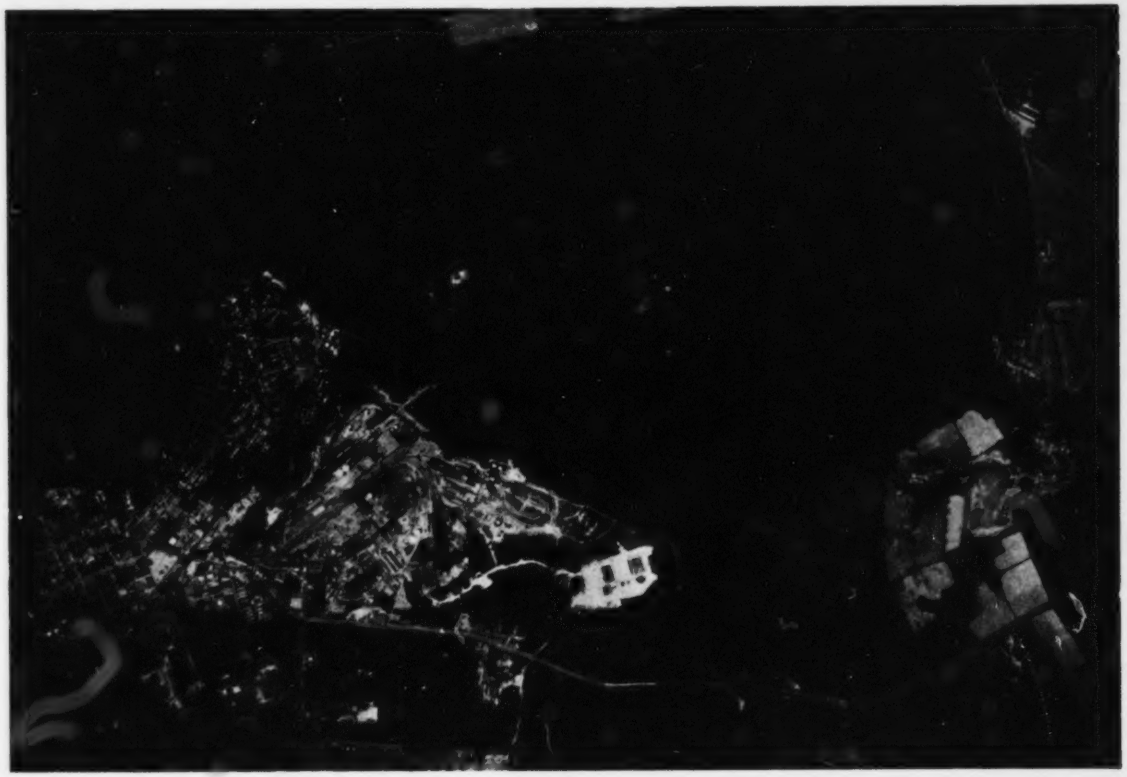

Figure B-1. AERIAL PHOTO OF BAILEY BAY SHOWING CIRCULATION PATTERNS. REPRODUCED FROM COLOR INFRARED PHOTO TAKEN AT 10,500 FEET (3,200 M) (Photo courtesy of NASA)

The water quality situation of Bailey Creek, Bailey Bay, and Gravelly Run may show significant improvement with the full operation of the Regional Sewage Treatment Plant (RSTP) in Hopewell located at the confluence of Bailey Creek and Gravelly Run. As of late August 1977, the RSTP is accepting all of the municipal sewage from Hopewell, which includes the industrial effluent from Firestone, and small portions of the sewage and effluents from Allied Chemical, Continental Can Company, and Hercules Powder. The latter are being accepted in order to build the biological floc micro-organism populations necessary to treat these wastes. As soon as the floc has been established, the larger scale treatment of the industrial wastes presently disposed of in Bailey Creek, Bailey Bay, and Gravelly Run can begin.

It is not expected that Fort Lee will be connected to the RSTP before October 1978. The delay seems to be due to negotiation problems at the Federal level (Hodell, personal communication).

If the plant successfully begins treatment of the effluents into the three water bodies late this year, a rapid improvement in the water color of the area can be expected. Odor may take several months to subside if the odor-causing substances are associated with the sediments. The BOD and low dissolved oxygen (DO) problem of the creek and portions of the bay may take several years to decrease due to the heavy nutrient and organic loading of the sediments as well as the shoaler depths at the creek's mouth. The sharp decrease in opacity of the water may allow intense algal growth to occur in the bay and creek. This would accelerate the cleanup of the nutrients in the creek and bay sediments, but the area will remain useless for most large aquatic organisms due to the extreme DO fluctuations which will result. The continuing input of nutrients from the Fort Lee effluents will also aggravate the situation until late 1978. After the effluents have been diverted to the RSTP, it is estimated that it will take several years before the system of Bailey Bay, Bailey Creek, and Gravelly Run reach a point suitable for the continued use of these waters by aquatic organisms. This will be due to the high residual levels of organic and inorganic polluting substances that will remain in the area's sediments.

THE ANALYSIS OF BOTTOM SEDIMENTS FROM BAILEY BAY, BAILEY CREEK, AND GRAVELLY RUN FOR VARIOUS CHEMICAL PARAMETERS

Ten sediment samples from the Bailey Bay, Bailey Creek, and Gravelly Run areas were obtained and analyzed for six heavy metals, chemical oxygen demand (COD), percent solids, sulfides, total Kjeldahl nitrogen (TKN), oil and grease, Kepone, chlorinated pesticides, and total polychlorinated biphenyls (PCB's). The first nine samples (see tables B-8 and B-9) were obtained by push cores on 14 April 1977; the tenth sample was obtained from the Route 156 bridge area by hand on 3 June 1977 (see plate B-6). The tenth sample could not be obtained on 14 April, and as a result was obtained when the data need for this location became apparent.

Only one chlorinated pesticide, Kepone, was detected in the ten samples. No PCB's were found at the 0.01 parts per million (ppm) level of detection. Kepone levels in the upper 25 cm of the cores ranged from a low of 3.7 parts per billion (ppb) or (0.0037 ppm) at the Route 156 bridge to a high of 48.25 ppm in the slough of the marsh just below the Route 10 bridge and on the shore of Bailey Creek. It is significant that the two highest Kepone levels determined were in samples from marshes on both sides of the creek.

The heavy metals including mercury (Hg), cadmium (Cd), lead (Pb), zinc (Zn), copper (Cu), and iron (Fe) did not indicate a common trend.

Mercury levels found in these samples were not excessive for the James River area. Levels found at river miles 66.50, 67.50, and 70.00 (Statute miles from Newport News point at the mouth of the James River.) ranged from 0.06 ppm to 0.21 ppm (United States Army Corps of Engineers, 1974). The high of 1.00 ppm at the mouth of Bailey Creek cannot be assigned any particular significance due to the absence of a trend in this parameter.

Table B-8 . RESULTS OF THE ANALYSIS OF SEDIMENT SAMPLES FROM BAILEY BAY, BAILEY CREEK, AND GRAVELLY RUN FROM PESTICIDES, INCLUDING KEPONE AND PCB'S

Sample Location	Parameters (ppm)		
	Kepone	Other Chlorinated Pesticides	Total PCB's
Jordan Point (1)	0.17	ND 1/	<0.01
Jordan Point, C.C. (2)	5.05	ND	<0.01
DM 109 (3)	0.02	ND	<0.01
Continental Can (4)	0.04	ND	<0.01
Gravelly Run (5)	0.03	ND	<0.01
Bailey Creek (6)	3.57	ND	<0.01
Upstream Bailey Creek (7)	8.10	ND	<0.01
Bailey Creek Marsh (8)	23.25	ND	<0.01
Bailey Creek Marsh (9)	48.25	ND	<0.01
Route 156 Bridge (10)	0.0037	ND	ND

1/ None Detected.

Table B-9. RESULTS OF THE ANALYSIS OF SEDIMENT SAMPLES FROM BAILEY BAY, BAILEY CREEK, AND GRAVELLY RUN

Sample Location	Parameters										
	Heavy Metals (ppm)										
	Hg	Cd	Pb	Zn	Cu	Fe(%)	COD%	Volatile Solids %	Sulfides (ppm)	TKN (ppm)	Oil & Grease (%)
Jordan Point, (1)	0.10	2.99	12.78	170	2.0	4.9	1.9	4.9	129	1855	0.2
Jordan Point, C.C. (2)	0.51	3.98	25.48	448	15.0	3.6	7.3	4.4	663	2959	0.5
DM 109 (3)	0.11	3.98	36.80	199	4.0	4.9	1.0	3.4	65	1597	0.3
Continental Can (4)	0.11	2.99	19.15	130	9.0	3.4	1.5	3.6	42	1057	0.1
Gravelly Run (5)	0.10	2.98	28.25	716	24.9	1.5	2.4	4.3	1449	939	0.3
Bailey Creek (6)	1.00	3.00	33.20	590	4.0	2.5	6.6	4.4	1091	2278	0.4
Upstream Bailey Creek (7)	0.27	2.00	19.20	420	4.0	0.5	2.5	4.7	679	1597	1.0
Bailey Creek Marsh (8)	0.10	1.00	19.20	230	4.0	7.1	3.8	4.7	168	3382	0.7
Bailey Creek Marsh (9)	0.32	1.00	39.00	2000	21.0	4.2	12.5	5.2	1385	10451	1.2
Route 156 Bridge (10)	0.10	2.00	52.00	190	38.0	1.6	2.5	4.25	521	2795	0.1

Cadmium was found concentrated in Bailey Bay inside an imaginary line from Jordan Point to the mouth of Gravelly Run. The lowest levels of cadmium were found in the marshes sampled on both sides of Bailey Creek. The low levels in Bailey Creek as compared to the bay may indicate that the cadmium is no longer dumped into the creek and has been flushed out or that the metal is being utilized in the marshes and sediments of the creek by the marsh plants and the micro-organisms presumably present. The range of values for cadmium (1.0 to 3.98 ppm) was considerably higher than the 0.3 to 0.5 ppm level found for three nonindustrial-use streams but was well within the range 0.2 to 12.1 ppm found in the Illinois River (Mathis and Cummings, 1973). The range of cadmium in Elizabeth River, Virginia sediments was found to be less than 1 to 26 ppm with an average of 4.0 to 4.2 ppm in the main branch of the river (U.S. Environmental Protection Agency, 1976).

Lead indicated a pattern of concentration that also differed from the other metals. The highest (52 ppm) and lowest (19.2 ppm) values were found in the creek. The high value at the Route 156 bridge may indicate that a source of lead exists above that point. The range of values for lead determinations in this area of the James River are 2.4 to 33.3 ppm (U.S. Army Corps of Engineers, 1973). The levels found in the study area coincide with lead levels in the James River near the project area. In the main branch of the Elizabeth River, lead ranged from less than 3 ppm to 242 ppm (U.S. Environmental Protection Agency, 1976).

Zinc exhibited a pattern of concentration around the mouths of Bailey Creek and Gravelly Run and also for a short distance up Bailey Creek. The high of 2,000 ppm in the Bailey Creek marsh (site #9) samples was noteworthy in that this maximum coincided with several other parameter maxima as seen from the table of sediment sample analysis results (table B-9). This situation is discussed in the subsection on future conditions without the project. The range of 130 to 2,000 ppm compares to a range of 14 to 56 ppm for nine river sediment samples (U.S. Army Corps of Engineers, 1973). The range of zinc concentration found in the main branch of the Elizabeth River was 65 to 1,690 mg/kg (ppm) with an average of 388 ppm The highest zinc concentration in the Elizabeth River was 2,380 ppm in the western branch (U.S. Environmental Protection Agency, 1976). Mathis and Cummings (1973) found zinc concentrations ranging from 6 to 339 ppm in the Illinois River and from 18 to 41 ppm in three nonindustrial-use streams.

The range of copper concentrations was from 2 ppm to 38 ppm just above the Route 156 highway bridge. The highest Pb level was also found at this location. The fact that these two maxima occur together may be coincidental or indicative of a source or sources for these metals above the bridge on Bailey Creek or its tributaries as already mentioned. The range of Cu concentrates found in main branch of the Elizabeth River sediments was from less than 2 ppm to 246 ppm (U.S. Environmental Protection Agency, 1976). The ranges in the Illinois River and three nonindustrial-use streams were 1 to 82 ppm and 3.5 to 11.2 respectively (Mathis and Cummings, 1973).

Iron is usually found in moderate concentrations in estuarine sediments. This is due to the relative abundance of this metal in the earth's crust and the chemistry of the estuarine system (U.S. Environmental Protection Agency, 1976). Iron ranged from a low concentration of 0.5 percent to a high of 7.1 percent in the project area sampled. In the main branch of the Elizabeth River, the range of iron concentrations ranged from 1.0 percent to 3.7 percent. The extremes for the entire Elizabeth River ranged 0.8 percent to 4.0 percent (U.S. Environmental Protection Agency, 1973).

The exact effect of the heavy metals present in the area cannot be predicted from the annalyses done as a result of this assessment. Excessive concentrations of Cadmium, Zinc, Copper, and possibly Iron may be causing negative environmental impacts on the area's biota. The synergistic or naturally reinforcing impacts of these metals with each other and the other inorganic and organic pollutants present can only be arrived at through speculation, since scientific analysis of these effects has not been extensively done.

The chemical oxygen demand (COD) of the sediment samples from the project area indicated a high trend. The range of values were 1.0 percent to 12.5 percent. Sediment samples from the James River near the project area exhibited a range of 0.81 to 7.72 percent (U.S. Army Corps of Engineers, 1973). The average of values for the James River and the project area were 1.94 percent and 4.2 percent, respectively. The maximum concentration of the COD parameter was found in the sample from the Bailey Creek marsh (site #9).

Volatile soilds (VS) followed the pattern similar to COD. The range of VS concentrations was 2.9 percent to 5.2 percent, with the average concentration being 4.3 percent in the project area. In the James River, VS ranged 0.4 percent to 4.6 percent, with an average of 1.9 percent (United States Army Corps of Engineers, 1973).

The parameter sulfides in the sediment analyses was done by distillation. This method probably determined the approximate concentrations of organic sulfides in the sediment samples. This parameter probably indicates the zones of influence of the plumes from the paper mills in the Bailey Creek area.

The analysis of sulfides in the sediment samples was done by extraction using distillation. Due to the high amounts of organic materials in the sediments, direct fixation of H_2S and inorganic sulfides was not possible. Use of this method probably determined the approximate concentration of organic rather than inorganic sulfides present in the sediment samples. The distribution of this parameter probably indicates the extent of influence of the effluent plumes from the paper mills in the Bailey Creek and Bailey Bay area.

The only major nutrient parameter determined was total kjeldahl nitrogen (TKN). The concentration of this parameter ranged from 939 ppm to the high of 10,451 ppm in the Bailey Creek marsh (site #9). Three values of TKN determined in samples from the James River near the project area were 144 ppm, 189 ppm, and 501 ppm. These were all lower than the lowest concentration found in the project area. The highest COD concentration determined in the James River was almost 2,500 ppm (United States Army Corps of Engineers, 1973).

In August 1977 an additional sediment sample, a sub-sample of a larger sample, was analyzed for the same parameters as the original 10 samples. In addition to Kepone several other chlorinated hydrocarbons were found. Polychlorinated biphynels (PCB) were detected at the 2.6 ppm level. The combination of peaks indicated that it was Aroclor 1254. The chlorinated pesticide scan indicated the presence of 0.14 ppm of para-para' DDE and 1.1 parts per billion of Ovex. Due to the relatively small number of stations analyzed for other chlorinated hydrocarbons, the reason for the non-detection of these other chlorinated compounds cannot be explained. It is noted however, that the mouth of Bailey Creek has been shown to be particularly polluted in other water quality parameters.

ENVIRONMENTAL SCENARIO OF THE PROJECT AREA

To provide input to the impact assessment for each of the 18 identified structural alternatives for capturing, stabilizing, or removing Kepone from Bailey Bay, Bailey Creek, and Gravelly Run, several reconnaissance trips to the area were carried out in August 1977. Also, since the numerous structural alternatives being considered varied widely in location and precise details regarding structure locations were not yet available, it was deemed appropriate to prepare an up-to-date environmental inventory map of the area. Such a map would then be useful in determining the amount of resources which would be involved with implementation of each of the identified structural alternatives, as well as with any combination of alternatives or additional alternatives which may subsequently be developed.

At the time of the reconnaissance trips, it was determined that the main areas to be impacted by the structural alternatives were downstream of the Route 156 bridge approximately 2.5 miles upstream of the creek's mouth (see plate B-7). For that reason, the majority of the reconnaissance work was done in that sector of the creek and on Gravelly Run.

No indepth surveys of the wetland resources of the lower Bailey Creek watershed could be located. Additionally, the latest revision of the USGS 7.5 Minute Series Topographic Map of the area (Hopewell, Virginia) was in 1969. Many recent developments have occurred in the area since 1969, including construction of a housing development, a waste treatment plant, and the expansion of the Hopewell city landfill. In light of the above and since only a limited amount of time was available for the indepth survey work, it was decided that up-to-date aerial imagery would be required to make the reconnaissance easier and provide the basis for the resource map. Under contract with the Corps of Engineers, the Virginia Institute of Marine Science (VIMS) photographed the lower Bailey Creek watershed (downstream of the Route 156 bridge) on 8 August 1977. Vertical aerial infrared, true color transparencies (70 mm) and true color prints were provided to the U.S. Fish and Wildlife Service for use in the preparation of the environmental inventory map. Additionally, 1:500 scale black and white enlargements of photographs from the Virginia Department of Highways were utilized. The photographs were vertical aerials taken in 1972. The infrared transparencies proved to be the most useful in delineating habitat boundaries. The ground truth data obtained during the August 1977 reconnaissance trips and the aerial imagery provided the information for detailed maps of the resources of the lower Bailey Creek Basin. The VIMS Bausch & Lomb Zoom Transfer Scope was used to reconcile differences in scale between the imagery and the 1969 topographic map. The resource map, which is shown on plate B-&, is a 1:24,000 scale and thus can be overlayed on the topographic map. The overlay delineates wetland and upland features, as well as local roads and the 10-foot m.s.l. contour. The upland and wetland features, as well as their utilization by fish and wildlife resources, are discussed below. The Hopewell, Virginia topographic map was used to determine the areas of swamp upstream of the Route 156 bridge. These areas were not photographed or visited.

BAILEY CREEK WETLANDS - WOODED AND MARSH

The majority of the area (approximately 419 acres or 169.5 hectares) within the Bailey Creek 10-foot m.s.l. contour consists of wetlands. The vast majority of these wetlands (345 acres or 139.6 hectares) is forested wetland or wooded swamp (U.S.D.I. Type 7, Wooded Swamp, Shaw and Fredine, 1956). This figure includes approximately 68 acres (27.5 hectares) of wooded swamp upstream of the Route 156 bridge. There are an additional 118 acres (47.7 hectares) of wooded swamp above the 10-foot m.s.l. contour upstream of the Route 156 bridge. Scattered fringe marshes and pockets of marsh (approximately 74 acres or 29.9 hectares) are found primarily along the creek banks. The vast expanses of wooded swamp and marsh on both sides of the creek provide a relatively secluded and diverse habitat area in close proximity to heavily industrialized Hopewell. The highly developed areas on the Hopewell side of the creek are, for the most part, obscured from view from Bailey Creek by the wetland areas, as well as some upland wooded areas (see plate B-7).

The upland/wetland interface is primarily one of abrupt transition between wooded swamp and upland due to the steep banks which surround most of the wetland portions of the basin. Numerous major tidal creeks are found within the swamp and marsh areas. It appears that most of the wetlands in the lower basin receive tidal inundation.

The soils in the wooded swamp were moist or waterlogged during the August 1977 reconnaissance. The predominant overstory species were pumpkin ash (*Fraxinus tomentosa*), white ash (*F. americana*), red maple (*Acer rubrum*), box elder (*A. negundo*), black gum (*Nyssa sylvatica*), and sycamore (*Platanus occidentalis*). Few areas of standing water within the wooded swamps were found and few trees were seen with swollen buttresses, a prominant feature in typical wooded swamp situations. Species composition was fairly constant throughout the lower basin. A few baldcypress (*Taxodium distichum*) were found near the mouth of the creek, however.

The predominant understory species within the wooded swamp are tree seedlings including the above-named species, lizard tail (*Saururus cernus*), poison ivy (*Rhus radicans*), jewelweed (*Impatiens capensis*), dodder (*Cuscuta gronovii*), and scattered marsh vegetation in lower areas, including pickerel weed (*Pontederia cordata*), arrow-arum (*Peltandra virginica*), and smartweeds (*Polygonum* sp.).

The next major creek system to the east of Bailey Creek with similar physiographic features is Powell Creek, approximately 5 miles downstream on the south bank of the James River. This creek was visited for the purpose of comparing its wooded swamps with those found on Bailey Creek. Larger numbers of baldcypress and black gum were found in the Powell Creek wooded swamps. Ashes and red maple are also present in the Powell Creek swamps as they are in the Bailey Creek system. Swollen buttresses on most trees were observed, and the floor of the swamp contained considerably more standing water than the Bailey Creek swamps. Bank lines (shorelines) are not as abrupt on Powell Creek as on Bailey Creek.

The two creek systems appear to be dissimilar from the standpoint of swamp elevation. The larger number of black gum and baldcypress on Powell Creek may be an indication of more frequent inundation. Whether or not these areas have always been different is speculative at this time. Bailey Creek is presently carrying an unusually heavy load of effluent-introduced suspended material. Most probably, during high flow periods, the creek floods the wooded swamps and the solids settle out. This is, of course, one beneficial function wooded swamps perform. However, over time the floor of the swamp may have been and is presently being raised. This may account for differences in species composition, lack of swollen buttresses, and lack of standing water.

The marshes of the lower Bailey Creek watershed are a diverse mixture of tidal freshwater wetland species (U.S.D.I. Type 12 Coastal Shallow Fresh Marsh Shaw and Fredine, 1956) or VIMS Type XI Freshwater Mixed Community (Silberhorn et al. 1974).

During the August 1977 reconnaissance, the predominant marsh vegetation observed in the fringe marsh areas was marsh amaranth (Amaranthus cannabinus) also known as tidemarsh waterhemp. The size of the marsh amaranth (upwards 8 to 10 feet tall), however, overshadowed the diversity of wetland species also found in these marshes. Such wetland species noted included pickerel weed, arrow-arum, rice cutgrass (Leersia oryzoides), smartweeds, marsh mallow (Althaea officinalis), and narrow leaf cattails (Typha angustifolia). Several small areas (no more than 1 to 2 acres in size) of separate pocket cattail wetlands (VIMS Type VI Cattail Community, Silberhorn et al., 1974) were found both within the previously described fringe marsh areas and in secluded pocket areas within the swamp. Near the main stem of Bailey Creek, wetland species composition is primarily narrowleaf and broadleaf (T. latifolia) cattails. In all areas where this type of wetland community was observed, intensive grazing on leaf tips by grasshoppers was noted. This grazing in the cattail areas accounts for the marsh "brown outs" observed in the aerial photographs.

Most of the marshes of Bailey Creek are found along the main stem of the creek with the exception of one large marsh which is separated from the creek by an extensive wooded swamp. This marsh is located adjacent to and south of the new Hopewell Regional Sewage Treatment Plant (see plate B-7). The marsh is connected with the main portion of Bailey Creek by a major tidal creek which traverses the wooded swamp just north of the Route 10 bridge. The marsh consists primarily of marsh amaranth, arrow-arum, and smartweeds near the eastern end while the westernmost area of the marsh is predominantly narrowleaf cattails. The extreme southwestern end of this marsh was cut off from the main body by the construction of Route 10. Although culverts are present, it is doubtful that the remnant marsh areas south of Route 10 (predominantly cattails) are tidally inundated. Additionally, the extent of tidal inundation of the main marsh could not be readily determined.

With the possible exception of the above-described marsh adjacent to the new wastewater treatment plant and very small scattered pockets of freshwater marshes on Cattail Creek, most of the swamp and marsh areas between the Route 156 bridge and the mouth of the creek are considered to be readily accessible to Bailey Creek for transport of export products through either frequent or infrequent tidal inundation.

By comparing the wetland areas delineated on the 1969 topographic map with the wetland areas mapped on plate B-7, it appears that at least several acres of marsh were lost since 1969 due to expansion of the city landfill adjacent to the Municipal Sewage Treatment Plant and filling activities associated with the construction of the new Regional Sewage Treatment Plant.

To aid in determining the extent to which the Bailey Creek wetlands are utilized by fish and wildlife, numerous trips were made up the creek in a small boat during morning, afternoon, and evening hours of 17, 18, 22, 23, 24, 25, and 26 August . Biologists from the U.S. Fish and Wildlife Service made observations of obvious wildlife usage through signs or actual sightings. See table B-10 for signs and sightings observed. The diversity of habitat types (wooded swamps, marshes, and upland woods) uninterrupted by housing, industry, or agriculture should provide conditions suitable for high diversity and numbers of animal populations. Although the purpose of this survey was not one of quantifying the numbers of a particular species, it did appear that the numbers of signs and sightings were well below what one would normally expect in a similar ecosystem. Most notable was the severely degraded condition of the water column and creek substrate. The odor of chlorine was quite strong after rainstorms while at other times, fecal and other unidentifiable, yet strong odors prevailed. Numerous outfalls entering the creek from the Hopewell side have, in the past, apparently eliminated the aquatic fauna expected in a similar, unpolluted creek system. As a result, wildlife utilization of the system is considered to be greatly reduced due to the lack of aquatic fauna which are important food chain components for many birds and aquatic furbearing species. Conspicuous by their absence were the commonly seen fisheating birds such as the belted kingfisher (Megaceryle alcyon), the great blue heron (Ardea herodias), and the snowy egret (Leucophoyx thula). The green heron (Butorides virescens) was the only exception to this general observation, however, it was seen on only one occasion. Songbird numbers also appeared to be lower than expected.

Table B-10. BIRDS AND MAMMALS OBSERVED ON BAILEY CREEK, AUGUST 1977

Animal	Sightings	Signs
Cottontail rabbit *Sylvilagus floridanus*		scat
Raccoon *Procyon lotor*		tracks, scat
Opossum *Didelphis virginiana*		tracks, scat
Mallards *Anas platyrhynchos*	2-3	
Green heron *Butorides virescens*	1	
Yellow-billed cuckoo *Coccyzus americanus*	4-5	
Red-tailed hawk *Buteo jamaicensis*	1	
Spotted sandpiper 1/ *Actitis macularia*	numerous 10	
Wood duck *Aix sponsa*	1-3	

1/ Seen on floating islands of flocculated material.

The lack of fisheating birds can readily be explained by the absence of fish fauna in Bailey Creek. The apparent low number of songbirds is difficult to interpret since there did appear to be food supplies available, especially grasshoppers in the cattail marshes. Also red-winged blackbirds, common residents of cattail marshes, were not observed in the Bailey Creek system.

Few signs of aquatic furbearers (either muskrat, mink, or beaver) were observed. Numerous "likely" marsh areas were investigated for signs of muskrat activity such as runs or houses, but nothing was found. It may be that the poor water quality and the lack of aquatic organisms as a food base component (clams, etc.) have eliminated the species from the creek. Several possible bank burrows were sighted, but their conditions indicated a lack of activity for quite some time. Some signs of raccoon were observed in the marshes and abundant signs were noted in the wooded swamps.

The U.S. Department of the Interior Presquile National Wildlife Refuge is located on the James River at Turkey Island a short distance (3.5 miles) upstream from Hopewell. A survey of the mammalian fauna of the wooded swamps on this refuge has yielded signs of opossum (*Didelphis virginiana*), eastern gray squirrel (*Sciurus carolinensis*), beaver (*Castor canadensis*), mink (*Mustela vison mink*), white tailed deer (*Odocoileus virginianus*), raccoon, and muskrat (Jackson et al., 1976). The rice rat (*Oryzomys palustris*), cotton mouse (*Peromyscus gossypinus*), and house mouse (*Mus musculus*) were actually trapped in the swamps (Jackson et al., 1976). Of the above-listed mammals, all should be expected to occur on Bailey Creek; however, the almost total lack of suitable aquatic components has surely limited the creek's value to at least the mink, muskrat, and beaver. It is not known to what extent the long-term polluted condition of Bailey Creek has affected utilization of the area by other wildlife species.

The value of the basin wetland areas to reptiles and amphibians is considered low in close proximity of the creek. It is believed that reptile and amphibian utilization of local resources increases with distance from the main stem of the creek. No turtles or snakes were observed on the banks of the creek or on fallen trees. Numerous sightings would normally be expected. One smooth green snake (*Opheodrys vernalis*), an insect eater, was observed high in the marsh amaranth fringing the creek. One water snake (Natrix sp.) was observed in a marsh a great distance from the creek. The paucity of amphibian and reptilian sightings tends to indicate that water quality or other environmental factors are limiting full utilization of the area by these animals. As in the case of fish, the water column appears to be the primary medium of suspicion.

As far as the fishery resources of Bailey Creek are concerned, the highly degraded water quality constitutes a severe pollution block which apparently has eliminated fishery resources from the basin for quite some time. This pollution block has prevented alosid spawning (VIMS, 1970). Spawning of Shad (Alosa) has been confirmed in Powell Creek and is probably in the numerous smaller creek systems nearby (VIMS, op cit.). Fish species sampled by Virginia Institute of Marine Science at stations on the James River 4 miles downstream and 6 miles upstream of Bailey Creek during the months of June, July, August, and September 1969 are listed below:

Blueback herring
Alewife
American shad
Hickory shad
White perch
Striped bass
Yellow perch
White catfish
Channel catfish
Brown bullhead
Gizzard shad
Bay anchovy
Silvery minnows

Spotted shiner
Catfin shiner
Hogchocker
Golden shiner
Silverside
Pumpkinseed
Longnose gar
American eel

High utilization of Bailey Creek by many of the above-listed species would be expected if not for the serious water quality problem at present.

BAILEY CREEK UPLAND FEATURES - INDUSTRIAL

Included in this category are the industrial complexes located only on the Hopewell side of the creek. Numerous cleared but barren areas adjacent to the industrial complexes were included in this category. In many cases such cleared areas were the sites of previous industrial works, including waste ponds.

Habitat values for areas within this category are considered low for most wildlife with the exception of small rodents. Other wildlife may venture into these areas from adjacent woodlands and wetlands.

BAILEY CREEK UPLAND FEATURES - WOODED

The upland woods on the Prince George County side of the Bailey Creek Basin are a southern hardwood oak-hickory association. White oak (Q. alba), trees of the red oak group including southern red oak (Q. falcata), and black oak (Q. velutina). Mockernut hickory (Carya tomentosa) and pignut hickory (Carya glabra), american elm (Ulmus americana), yellow poplar (Liriodendron tulipifera), american beech (Fagus grandifolia), and harkberry (Celtis occidentalis) were species most commonly noted. The understory consisted of tree seedlings including the above-named species and red maple, pawpaw (*Asimina triloba*), witch hazel (*Hamamelis virginiana*), greenbriar (*Smilax* [*rotundifolia*]), and poison ivy. The woodlands are extensive and relatively intact along the southern border of the basin. Industrial and residential developments have greatly reduced the amount of upland wooded areas on the north (Hopewell) side of the basin to only one relatively large area on the southwest side of the Route 10 bridge.

This type of habitat generally supports a varied mammalian fauna. White tailed deer, gray squirrel, cottontail rabbit, flying squirrels, gray fox, opossum, bobcat, skunk, raccoon, and various microtine rodents are species most likely found in this type of habitat. Of the above-listed species, all, with the possible exception of the bobcat, are expected to be found in the wooded areas on the south side of the basin and to a limited extent in the remaining wooded areas on the north side of the basin. Songbirds, woodpeckers, raptors, and owls are birds one would expect to utilize the habitat.

The wooded area across Route 10 to the south of the Allied Chemical Plant (plate B-7) is dissimilar to the wooded areas previously described. This side contains large areas of remnant industrial building foundations. Tree species include black cherry (*Prunus serotina*), persimmon (*Diospyros virginiana*), sassafrass (*Sassafras albidum*), willow oak (*Quercus phellos*), and princess tree (*Paulownia tomentosa*).

The understory in this area is relatively sparse. Grasses and woody vines, as well as small holly trees, appear to be the most numerous understory species.

Speculation on the wildlife utilization of this area due to its apparently stressed nature is difficult. A rather large number of trees were dying or dead (black cherry seemed to be the most affected) indicating that there may be limiting factors affecting habitat quality in this area. During the site inspection, the area was permeated with a most unpleasant odor, apparently emanating from the nearby industrial complexes. It is not known what effects such circumstances may have on the wildlife utilization of this particular area. This area will not be impacted by the structural alternatives being considered by the Corps of Engineers.

BAILEY CREEK UPLAND FEATURES - AGRICULTURAL AND RESIDENTIAL

This category includes all residential and agricultural areas (including fallow fields) as well as brushy clearings associated with powerline and highway rights-of-way (see plate B-7).

The Hopewell side of the study area contains no agricultural areas. The Arlington section of Hopewell is the principle residential area within this otherwise industrialized area. Much of this area is adjacent to and drained by Cattail Creek. Single family housing is currently being constructed in a small subdivision adjacent to Bailey Creek northeast of the Route 156 bridge. This residential expansion is included on plate B-7. The remainder of the areas within this category in this portion of the basin consist of powerline rights-of-way and brush-covered lots.

The Prince George County side of the study area contains sparsely located residential buildings, the majority of which are located near Route 646. One small, single-family housing development has been constructed off Route 646 northward toward the creek. This development is located in close proximity to the Hopewell Sewage Treatment Plant which is to the southeast across Bailey Creek. The remainder of the areas within this category consist of agricultural fields and powerline and highway rights-of-way. No census of crops raised was taken; however, it is expected that corn and soybeans with possibly some peanuts and tobacco are raised in this area. Family garden plots also exist. Since most of the residential, agricultural, and powerline and highway rights-of-way areas have been carried out of the previously described upland wooded areas, their value to area wildlife is primarily due to the creation of "edges" which allow for habitat diversity. Such edges, especially those located near croplands provide excellent habitat for numerous upland wildlife including the cottontail rabbit, white-tailed deer, red and grey foxes and raccoon.

Cattail Creek, the largest tributary of Bailey Creek downstream of the Route 156 bridge, runs in an approximate northward direction from a point approximately 2 miles upstream of the mouth of Bailey Creek. Most of the Cattail Creek drainage area has been developed industrially on its eastern side and residentially on its western side. The Hopewell city landfill is located on the southwest section of the creek's watershed near the old Municipal Sewage Treatment Plant. With the exception of some upland wooded areas remaining near the Arlington residential section, most of the area surrounding the creek has been cleared. The remaining areas are swamp and marsh (approximately 14 and 9.5 acres, respectively) found below the narrow 10-foot m.s.l. contour. Many of the marsh areas are perched, due probably to earlier land moving activities. Aside from the wetland habitats afforded by Cattail Creek, the wildlife value of this highly modified area is considered low.

GRAVELLY RUN

Gravelly Run is a small tributary of Bailey Bay located approximately one-fourth of a mile upstream of the mouth of Bailey Creek. Note on plate B-7 that except for a small band of upland trees (most of the species described for the upland wooded category are found here), the entire eastern margin of the creek has been developed industrially. A small upland wooded area on the west side of the creek is separated from the creek by what is apparently a dirt road. Only limited access to the area could be located; however, ground observations were made through various observation points at road crossings and from both banks at the lower end of the basin.

The wetlands near the mouth of Gravelly Run are primarily wooded swamp contiguous with the Bailey Creek system. The remainder of wetlands in the basin are freshwater marsh characteristically similar to those found on Bailey Creek but with slightly different marsh species predominating. Narrowleaf cattails widely interspersed with jewel weed, hibiscus, upland shrubs, and young willow trees seemed to predominate the marshes of the basin.

An extremely high flow of water was noticed in Gravelly Run. Over 120 million gallons per day of effluent is discharged into the upper headwaters of Gravelly Run by industries (Haluska, personal communication). Additionally, a large discharge of effluent from the Regional Sewage Treatment Plant empties into Gravelly Run a short distance upstream of its mouth.

Little is known about the fishery resources of Gravelly Run; however, the discharges and water within the creek seem to be very similar in appearance to Bailey Creek waters. Accordingly, it is doubtful that much exists in the way of aquatic fauna on Gravelly Run.

The banks of Gravelly Run are steep and densely wooded. The limited habitat provided by the wetlands and adjacent woods would be utilized to some extent by most birds (except fisheating and other shorebirds), small mammals (with the exception of aquatic furbearers), reptiles, and amphibians (higher occurrence of these species expected with increasing distance from the creek and decreased dependence on aquatic fauna).

BAILEY BAY

Bailey Bay is the shallow embayment with depths generally 1 to 2 feet (0.3 to 0.6 meters) at mean low water into which both Gravelly Run and Bailey Creek empty. The shallow waters are the habitat for numerous benthic animals and fish, both resident and migratory, within the James River system. It is expected that the degraded water quality of waters entering the bay from Bailey Creek and Gravelly Run have affected the habitat value of the bay. The extent to which the habitat has been degraded would depend greatly upon circulation patterns within the bay. NASA Langley Research Center's investigations into surface mapping of plumes emanating from both Gravelly Run and Bailey Bay in conjunction with data taken by Battelle Northwest Pacific Laboratories may aid in the determination of the maximum extent of likely habitat degradation in the bay.

Poor water quality as a result of long-term municipal and industrial discharges and large-scale clearing of wooded acres in Hopewell appear to be the major factors affecting area habitat quality insofar as fish and wildlife resources are concerned. Stream habitat value to fishery resources in Bailey Creek and Gravelly Run is considered detrimental, and this is manifested by a lack of fish in the creeks. It is expected that the pollutant discharge plumes emanating from Gravelly Run and Bailey Creek affect fishery habitat quality to some extent in Bailey Bay through long-term reductions in dissolved oxygen and introduction of concentrated effluent which may cause "avoidance" responses in fish.

Adverse impacts to wildlife have occurred through the elimination of aquatic fauna upon which certain birds and mammals depend. The value of these systems to fisheating birds, certain reptiles, amphibians, aquatic insects, and aquatic furbearers is considered nil. Additionally, low utilization of the area by waterfowl may occur due to high chlorine and other pollutant levels in the creek at certain times of the year.

Although the value of the aquatic component of Bailey Creek is very low, the lower creek basin is considered to have high wildlife value in terms of its wetlands and woodlands, especially those woodlands on the Prince George County side of the creek. Since the health of the whole system is directly related to the health of all components, it is apparent that the stress of degraded water quality on the aquatic system has degraded not only the streams but the whole ecosystem. However, the relatively undeveloped wooded swamp, marshes, and woodlands of the area are still of high habitat value to those species not directly dependent upon the aquatic resources of the creek. The marshes and wooded swamps are still performing their functions and thus maintain not only high habitat values for wildlife species but produce a vast amount of organic material for aquatic resources in the James River system.

From the standpoint of productivity, the Bailey Creek area is considered to be an important component of the James River ecosystem. The hundreds of acres of swamps and marshes provide nutrients which are carried to the James River by tides and storm waters. Conner and Day (1976) describe swamps as follows:

> "Swamps differ from terrestrial forests in several ways. In upland forests, land and water have definite boundaries, and nutrient cycles tend to develop as forests mature so that only small amounts of the available nutrients are carried away in drainage waters. Thus, mature terrestrial ecosystems tend toward a state where minimum erosion and transport of dissolved and particulate matter occur (Likens and Bormann, 1974). In the

> swamp, however, land and water are not readily separable . . . Nutrients taken up by plants are exported as organic detritus via litterfall and rapid decomposition . . . High waters then flush out nutrients not already back into vegetation."

In their study of the productivity of a bottom land hardwood swamp in Louisiana, Conner and Day (op. cit.) calculated the amount of litterfall at 574 g dry wt/m^2/yr. Also measured were stem biomass production (800 g dry wt/m^2/yr.) and understory biomass production (200 g dry wt/m^2/yr.). Of the above, the litterfall and annual herbaceous understory are the most direct export components produced by the swamp each year. The Louisiana swamp studied is somewhat similar to the Bailey Creek and Gravelly Run swamps in terms of tree species.

If we calculate leaf litter productivity of the Bailey Creek and Gravelly Run swamps using only the leaf litter production figure developed for the Louisiana swamp, we believe that the resulting figures are conservative because we have not included understory biomass production or organic exports from stem decay. A slight decrease in productivity values should be expected on the Bailey Creek and Gravelly Run swamps due to the 7 degree increase in latitude over the Louisiana swamp, however. Thus, for the 277 acres (112 hectares) of swamp on Bailey Creek below the Route 156 bridge, production of leaf litter is estimated at 678 tons (615 metric tons) per year (see table B-11).

Table B-11. PRODUCTIVITY AVAILABLE FOR EXPORT FROM BAILEY CREEK AND GRAVELLY RUN MARSHES AND SWAMPS (TONS PER YEAR AND METRIC TONS PER YEAR)

	Bailey Creek (above Rt. 156 bridge)	Bailey Creek (below Rt. 156 bridge)	Gravelly Run
Swamp	455 (412) 1/	678 (615)	35.5 (32.0)
Marsh	0 (0) 2/	298 (270)	38.0 (34.0)

1/ Based on 2.44 tons/acre/yr. (Conner and Day 1976).
2/ Based on 4 tons/acre/yr. (VIMS 1974).

Annual biomass production of the marsh (VIMS Type XI Freshwater Mixed Community) was calculated by VIMS at 3 to 5 tons per acre per year (Silberhorn et al., 1974). The value of these marshes as sources of nutrients to estuarine ecosystems has been well documented. These marshes are also of value as producers of seeds which are heavily utilized by songbirds and waterfowl. Smartweed and tidemarsh waterhemp, which are abundant on Bailey Creek, produce seeds which are favored by mallards, pintails, teal, wood ducks, and black ducks to name only a few (Martin et al., 1951; Martin and Uhler 1939).

Thus, the export components of Bailey Creek and Gravelly Run should be considered as significant inputs to the James River system when analyzing the impacts which various structural alternatives will have on Kepone export from these systems. The interaction of these export materials with Kepone and the other pollutants which have been shown to have an affinity for organic materials will also be considered.

FUTURE CONDITIONS WITHOUT ANY PROJECT

The projection of the future conditions of an area is an inexact science at best. For the purposes of this study, conditions through the year 2000 will be projected.

The population for this area is estimated to continue growing through the next 25 years, with the county growing faster than Hopewell. State projections show an increase from 23,300 in 1975 to 27,700 in 2000 for Hopewell and 18,700 to 31,500 for Prince George County. Development in Hopewell is expected to occur in the southern and western parts of the city and its vicinity; in Prince George County it is forecasted to take place in the more developed areas of the county, especially near Petersburg and Hopewell. This projected development will not strain the natural environment excessively if zoning and subdivision ordinances and land-use plans are followed along with all environmental regulations and guidelines. No major changes in the economic base of Hopewell are anticipated. The future of Prince George County is less certain because of its dependence on Fort Lee and lack of industrial development of its own. It is expected that the county will continue to provide housing for workers in Petersburg and Hopewell.

A radical improvement in some water quality parameters will occur with the operation of the Hopewell Regional Sewage Treatment Plant (RSTP) near the end of 1977. The operation will shift the point of input of pollutants and contaminants from sources along Bailey Creek to one outfall near the mouth of Gravelly Run. The most significant effect of this change will be the color change and the reduction in pH and BOD of the Bailey Creek waters. Oxygen levels now found in the creek will probably remain the same for 5 to 10 years due to the probable high sediment BOD levels. The decrease in pH may make the heavy metals present in the sediments more available to the ecosystem. This process will continue for some time (10 to 20 years) as the competing sedimentary organic material (oil and greases, etc.) are degraded. Exact biological invasion rates to the now apparently depauperate area cannot be accurately determined. Benthic invasion may occur by opportunistic, pollutant tolerant species. This rate will depend, of course, on the effect the remaining sedimentary pollutants including toxic substances and chemical parameters, such as sediment BOD, have on these organisms.

Some waterborne biota may be able to use the area for feeding during the next 5 to 10 years. After this time, some spawning and breeding may take place in the area. These occurrences may cause accelerated rates of heavy metal and chlorinated hydrocarbon uptake by these organisms due to the high levels of these substances in the creek and bay. The natural degradation of these compounds does not appear to be significant under presently understood circumstances. This applies to the PCB's as well as Kepone.

The stress on the marshes, swamps, and upland ecosystems, as well as the aquatic ecosystems, will decline as the inputs of contaminated and polluted water are minimized or treated and as the sediments undergo chemical alteration and burial. Uptake of organic and inorganic pollutants will continue, however, until these transformations are complete. This will cause the continuing distribution of these pollutants in the area's ecosystem, as well as in the James River.

The suburban development of the vacant area on both sides of Bailey Creek may increase the stress to the marshes and swamps adjacent to the creek by adding storm-water runoff to the stream. This process may prevent the marshes and swamps of the project area from regaining their present habitat potential.

As mentioned above, the area will cause the continuing distribution of Bailey Bay area pollutants to the James River ecosystem. This process may be overshadowed by the rapid improvement of some water chemical parameters such as color, organic sulfides, and pH. Although the long-range effects of these parameters on the downstream James River system are not known, it is surmised that the removal or correction of these parameters will greatly aid the downstream ecosystem, as well as the removal of any other pollutant.

In summary, the county and city will continue to grow at a moderate pace. The ecosystems of the area will benefit by the operation of the Regional Sewage Treatment Plant. However, this benefit may allow increased migration of pollutants from the area in the food web. After an initial improvement in the biological systems, this increased migration may significantly alter the long-term quality of these systems. Little or no change is seen in the air quality of the area.

IMPACT OF THE PROPOSED ALTERNATIVES ON THE PROJECT AREA

The lack of reliable background data on the project area and the heavy industrialization of this area have combined to make the assessment of the environmental impact of the alternatives under study difficult in some cases. For example, the application of the Fish and Wildlife Service's Habitat Evaluation Procedures were difficult to design even in a modified form (due to the short time frame of the study) because of the excessive pollutant loading of Bailey Creek.

The impacts of the various alternatives on the archeological resources of the project area were also difficult to assess at this stage. Since extensive archeological surveys along the creek banks have not been done, all existing sites may not have been discovered. The plan for this parameter of the analysis is to initiate the necessary survey investigations when most of the proposed alternatives have been eliminated from further consideration. This would allow a more indepth reconnaissance study of the remaining alternatives.

Overall, the largest problem in assessing the impacts of the several alternatives was the effect this area has had on the James River over the years. Even without Kepone, the Bailey Creek area has been a point source of pollutants for the James River ecosystem for many years.

This problem will become obvious when the environmental impact of the alternatives on the project area's swamps and marshes is addressed.

SOCIAL AND LAND-USE IMPACTS

As presently formulated, only a few of the alternatives will have more than the minor social impacts associated with construction activities, such as minor traffic congestion from machinery and increased atmospheric suspended particulates.

Alternative 1 will cause a minor disruption to the operations of the Continental Can Company during severe flood conditions since the bridge which logging trucks use would be covered by the impounded runoff. No change to current land-use patterns or major adverse social impacts can be expected to occur from this plan.

Alternatives 2 and 3 would have little effect on land-use plans in the Gravelly Run area and little, if any, negative social impact.

Consideration of Alternatives 4 and 5 was discontinued after it was determined that the method of construction for these was more expensive than for Alternative 3, and these alternatives offered no increased control of the Kepone contamination.

Alternative 6 was determined to have no impact either to social factors or to land-use in the Gravelly Run area.

Alternative 7 would not involve any relocations of people or buildings and would not adversely affect the current or future land-use plans for the Bailey Creek area.

There are no serious adverse social impacts which would result from Alternative 8. In addition, this plan does not conflict with land-use for either side of the creek. The northwest side is zoned industrial, and all buildings in this area are far enough away from the creek so that they would not be affected by this channel modification. The undeveloped state of the southeastern side of the creek presents no land-use conflict with this alternative. In fact, Prince George County has proposed that its half of the creek, its tributaries, and their banks be classified as critical environmental areas where no construction would take place, thus precluding any development which would adversely affect this alternative.

Alternative 12 would involve the evacuation of approximately 25 structures, many of which have been recently built. Most of these structures are single-family dwellings which are located in an area zoned for residential development. The residents of these houses would be relocated according to the provisions of Public Law 91-646, the Uniform Relocation Assistance of Real Property Acquisition Policies Act of 1970. Although the residents would receive monetary compensation for their property, they would still be forced to move, whether they wanted to or not. Possible adverse effects of such an action on the residents include economic loss, psychological stress, and a decrease in community cohesion.

This alternative may preclude development of a few sites near the creek on the Hopewell side, which would have been used for housing. However, most of the undeveloped area behind the dam lies above the 50-foot contour and would not present a problem to the plan if it were developed. In Prince George County it is anticipated that the land near Bailey Creek will eventually become a residential area with the creek banks and adjoining flood plain left as a natural area. Since no construction has occurred yet in this area, provisions could be made so that no buildings would be erected which would conflict with the proposed plan.

Additional social impacts will result if the placement of the diversion conduits to Chappell Creek along Virginia Route 646 is chosen. This route would disrupt many houses along its path, as well as traffic operations along the road. It is estimated that this route would require a 100-foot (30.5 m) right-of-way.

BENEFICIAL SOCIAL IMPACTS

All of the alternatives under consideration would have essentially similar social benefits. Perhaps the greatest benefit would be the reduction in the health hazard currently posed by Kepone and other toxic substances which may continue to infiltrate the James River system from Bailey Creek. Closely associated with this effect would be the economic benefits which would accrue to the seafood industry along the James River in particular and the lower Chesapeake Bay in general. Any alternative which might reduce further influx of Kepone and other contaminants from Bailey Creek into the James River might reduce further seafood contamination and hardship to the fishermen in the area. Both the commercial seafood industry and the sport fishing industry have been severely affected by Kepone contamination and the resulting fishing restrictions. Consumer confidence in the safety of eating seafood has been eroded, resulting in seafood sales reductions. Enactment of any of the alternatives might help to restore this confidence in the safety of consuming seafood. It might also enable the fishermen and other watermen to continue to earn a living from their lifelong trade and provide an aid to the supporting water industries.

IMPACTS ON ARCHEOLOGICAL AND HISTORICAL RESOURCES

The majority of the alternatives would have little or no impact on the known archeological sites in the project area (see plate B-5). The damming and covering alternatives would not affect the makeup of the known or unknown sites except at the damsites and treatment plant sites. The covering options may provide protection to several of these sites (PG 32 and PG-9) and allow further excavation when funds are available. An adverse impact from the dammming options would be that the sites of any investigations in the impoundment area would be subject to flooding if sufficient precipitation occurred. Archeological investigations would be conducted at the sites of any dam, spillway, or treatment works required for this undertaking. Preparation of the disposal area in Bailey Bay might require that site PG 34 be disturbed. If this is the case the bay bottom would be profiled to locate possible underwater sites, the balance of the affected bay shore would be surveyed, and this site and any others found would be salvaged.

Of the nearby properties on the National Register of Historic Places, two may have the vista from that site impaired. As seen from Eppes Island, the dams at the mouth of Bailey Creek and the Bailey Bay disposal areas would potentially cause the most impact. The distance from Eppes Island to the creek mouth is approximately 2 miles. At this distance, a 27-foot (8.4 m) structure would barely be visible, especially when contrasted against the adjacent industrialized Hopewell shoreline.

The longest disposal area levee in Bailey Bay would be 14.250 feet (4.4 km) in length. Depending on the color of the stone used to construct the levee, a 10-foot (3.1 m) structure of 2 miles distance would be difficult to see, especially in the turbid air usually seen in this area. If light stone is used, the levee would be potentially more visible until the stone darkens by weathering. This impact would also be lessened by the unimpaired view of the tree-covered southeast shore of Bailey Bay.

It is doubtful that any visual impacts would accrue to the Appomattox Manor site at City Point since its vista is already impaired in this direction by housing and industrial development.

IMPACTS ON THE NATURAL ENVIRONMENT

The largest Gravelly Run dam (Alternative 1) would require the clearing and site preparation of 3.2 acres (1.3 ha) on both banks of the creek. Although there is some question as to the value of this habitat because of the presence of organic and inorganic pollutants, the rehabilitation of this acreage would be precluded. Although the dam would have greater replacement surface area, it would not afford the habitat uses that are being destroyed. The spillway and treatment plant sites are included in this acreage.

Construction activities will disrupt the patterns of any resident animals and will tend to drive them away from the area. This may be a beneficial impact in that wildlife is kept out of contact with an area containing potentially toxic substances.

The dam will alter the flow and drainage patterns of the creek. Tidal influence on the creek's wetlands will cease, which may cause the character of the inclosed wetlands to change. If the amount of ground water input to the wetlands is insufficient, the vegetation in these areas will gradually become more mesic or even xeric. A rapid disappearance of the swamps and marshes will disrupt what few inhabitants there are in the Gravelly Run area. The energy flow from the Gravelly Run system in the form of detritus will cease. This loss of energy input to the Bailey Bay - James River ecosystem will cause a short- and long-term decrease in this system's productivity. The remaining habitat provided by this area may act as a vehicle for the uptake of pollutants in the sediments.

When a flood occurs up to the 100-year frequency, the impounded waters can be expected to be highly polluted because of the runoff from industrialized areas and the presence of leachates from polluted stream

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sediments. The presence of this water for up to 3 week will exclude the area wildlife, and may also affect the vegetation at the lower levels of the basin since these areas will be inundated for the longest period of time.

During floods in excess of the 100-Year Flood, some waters will be released over the spillway without treatment. If the flood is far in excess of the 100-year event (e.g., 200 yrs. +), serious degradation of water quality in Bailey Bay can occur.

In addition to the impacts listed for Alternative 1, Alternative 2 would involve the transfer of water to a wetland area adjacent to Bailey Creek. While this plan would eliminate the treatment works and its impact to the Gravelly Run area, there would be a great deal of alteration to the receiving marsh area. Some of this alteration would be minimized (see Section C) if the outfall from the Regional Sewage Treatment Plant is relocated to a site outside the impoundment. The diverted runoff will still be heavily polluted and may affect the receiving marsh and dependent systems. This marsh will also be affected by the alternative chosen for Bailey Creek.

The very high amounts of heavy metals and other pollutants found in a sediment sample from the slough draining this area may indicate that the value of this area to the ecosystem is limited. If this is shown by subsequent experiments, the alteration of the Gravelly Run area to a biologically unuseable form may be beneficial to the James River ecosystem. This would be done by Alternative 3.

Little impact is anticipated from placing the 1,000 ft. (305 m) of diversion pipes in this industrialized area.

The covering of 30 acres (12.1 ha) of the Gravelly Run Basin as required in Alternative 3 would destroy any habitat within the covered area. The 3 feet (1 m) of cover may keep the pollutants in the sediments.

The rising of the creek bottom 3 feet would probably remove most of the presently tidal portion of the creek from this influence. This would preclude the development of tidal wetlands on top of the cover.

Instead of the redevelopment of part of this area as a wetland, a layer of topsoil will be put over the pollutant cover layer and seeded. Management of this area as a meadow will have an amelioratory impact on the environment; in fact, it may have a net beneficial impact on the ecosystem if pollutant uptake in organisms from the present area is deleterious. Studies of the effectiveness of the proposed cover in preventing pollutant input to the adjacent ecosystems will be necessary to evaluate the beneficial environmental impact this alternative will have in lessening pollutant concentrations in the environment.

The new streambed to be developed on top of the cover will have little value to wildlife due to its imtermittent nature and the effect that polluted "slugs" of storm-water runoff will have on any life which may develop here. It is assumed that the Continental Can Company and Allied Chemical Corporation's discharges to the creek will be routed through the Regional Sewage Treatment Plant.

The flows from the reconstructed stream will have a greater effect on the Bailey Bay water quality than the spillway overflows of the first two alternatives which were damming and covering. This is primarily due to the fact that the intermittent spillway flows on the average of once every 100 years will have a short-term impact on the bay and river system, whereas the relatively permanent and long-term nature of the input of area runoff (some of it containing toxic materials) can be projected as having moderate to serious chronic ecosystem effects.

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Alternatives 4 and 5 were not considered since they were more costly than Alternative 3 and did not provide any additional pollutant control.

Removal of contaminated sediment in Gravelly Run can be effected by Alternative 6. However, the preferred method of dredging (dragline) may reduce the efficiency with which contaminated sediment can be removed. If the pollutants can be essentially removed, the reconstruction of marshes in the area may be possible, thus possibly lessening any net adverse long-term environmental impact from this alternative. The marshes and swamps presently in this area are not generally of the type and composition to be considered high quality habitat. In fact, it is doubtful that this area provides much habitat value to the area's ecosystems. This minor value may be outweighed by the damage this area does to the James River ecosystem as a toxic substance source.

The environmental impact of Alternative 6 also depends on the site of the dredged material disposal area. The size of the disposal area must be at least 20 acres (8.1 ha). It is proposed that the best locations for such an area would be the Bailey Creek tidal areas or the Bailey Bay bottom since this area is already contaminated by toxic substances. This siting could avoid environmental impacts from placing the dredged material on upland or on relatively uncontaminated aquatic bottom. The environmental impacts of this type of siting could occur through the secondary contamination of the ground water, upland ecosystems, overlying waters and/or aquatic ecosystems from these placements. If an upland (non-aquatic) disposal area is used for the dredging activity, site preparation to prevent ground water contamination may be necessary.

Pollutant movement from the disposal area will be minimized by a water treatment facility. This plant will remove suspended material and dissolved organic pollutants in the return flow from this area.

Removal of the suspended material, which includes suspended sediment and detritus, will prevent the possible uptake of these pollutants by the James River food web. Removal of the suspended organic and inorganic materials by such a facility will eliminate essentially all the pollutants from the effluent of the disposal area. The release of detectable amounts of chlorinated hyrocarbons into solution during dredging operations was not found in laboratory studies (Chen et al., 1976). This study also found detectable releases of trace metal contaminants from dredged materials but in levels less that those proposed for open-water disposal criteria.

The possible introduction of trace metals into the food web by plant uptake and of organochlorine compounds by atmospheric transport may occur from an open disposal area. The sealing of the exposed surface of the area will be done to prevent this. A material which is impervious to air and water will be used as the sealant. One material which has been suggested is clay.

Aquatic siting of a disposal area will destroy the productive potential of the bottom area covered by the dike and dredged material. The term productive potential is used because it is felt that the benthos present in this area have been either eradicated or excluded from the area due to the presence of high levels of organic and inorganic pollutants in the area's sediments and waters. The replacement of the estuarine bottom with an upland area covered by clay will not replace even the small productivity of this bottom. Mitigation of the productivity loss can be accomplished by covering this area with topsoil and seeding it with grasses and annual plants. The area must be maintainted as a meadow to prevent the growth of deep-rooted shrubs and trees which could penetrate the cover. An estimate of the length of time this cover must be maintained cannot be made.

Air quality may be degraded by the introduction of suspended particulates during disposal area diking and covering operations. During dredging some organic materials in the dredged material may be released into the atmosphere in the disposal area. No long-term degradation of air quality is anticipated as photo-oxidation of these materials will occur rapidly. No long-term release of these materials from the covered disposal area is expected.

Damming Bailey Creek and treating the runoff of the watershed up to the 100-Year Flood height was considered under Alternative 7. Several long-term impacts on the local ecosystems would occur from this action.

The dam would stop the tidal cycling of waters in the creek. The tidal cycling provides necessary moisture and nutrients to the low marshes and wooded swamps of this area. The cycling also supplies the aquatic ecosystem with detritus from the wetlands. At present the effect of the pollutants associated with the detritus is not known. It can be projected that the low marshes would be seriously affected during the first growing season, while the wooded marshes would begin to show serious alteration after 5 or 6 growing seasons.

The flooding of the area behind the dam during periods of heavy rainfall would probably have a more serious impact on the wetland areas if a 10-or 50-year frequency rainfall occurs in the first several years after construction. Since areas would be inundated for up to 3 weeks, depending on the size of the treatment plant, wetland plants and trees might die or be seriously damaged.

Passing the impounded waters through a suitable treatment plant will remove pollutants entrained in the effluent water. This will have a net positive effect on the Bailey Bay and James River ecosystems.

Cycling of pollutants to the environment by organisms might still result from the marsh and swamp areas behind the dam although the rapid degradation of these areas during the first 5 to 10 years of the project might restrict these areas' full potential use as habitat. After the area has stabilized, increasing use of the area might cause increased pollutant loads to the environment with serious long-term effects.

The construction of the dam would require the clearing or covering of 4 to 6 acres (1.6 to 2.4 ha). The productive potential of the dam would not equal the potential of the covered estuarine bottom and upland vegetation at the dam site. However, the loss of the estuarine bottom in its present degraded state would not seriously affect the local ecosystem of the James River.

The hauling of materials for the dam might cause an increase in suspended particulates in the atmosphere along the haul route. Even with a local increase in motor vehicle emissions along this route and at the construction site, no long-term adverse effects on air quality are anticipated.

Noise from the construction activities will not cause any impacts to the human or animal populations of the project area due to the site remoteness from residential areas and the apparently depauperate nature of the surrounding ecosystem.

Alternative 8 proposes the covering of the Bailey Creek bottom area contaminated by Kepone up to the 5-foot (1.5 meter) contour.

This alternative would completely eradicate the marshes and swamps in the covered area. Although these areas are severely stressed by the pollutant loadings of Bailey Creek, including nutrients, they still provide valuable habitat for some upland and nonaquatic plant and animal species. The top surface of the fill area would allow the construction of a stream-oriented upland ecosystem on the upper surface of the 3-foot (1 meter) thick covering layer to mitigate the loss of this wetland area. Management of the area to prevent the penetation of the cover layer by plants as well as erosion of the cover would be necessary for a considerable amount of time. Until a breakdown pathway for the covered pollutants is identified, a management time in excess of 100 years would be considered necessary. The replacement of the polluted estuarine habitat by a relatively unpolluted managed meadow may mitigate this adverse impact.

The streambed of the "new" ecosystem would not carry the pollutant loadings of the present streambed. While water in the "reconstructed" stream would not be as polluted as the present stream, it might contain enough pollutants and toxic materials to prevent the new streambed from reaching its full biological potential. In addition, the new streambed would have almost no estuarine character, thus limiting any potential peak productivity to that of an upland Piedmont stream in a moderately populated and heavily industrialized area.

The impacts of hauling 2,246,000 cubic yards (1,717,000 cubic meters) and 156,000 cubic yards (119,300 cubic meters) of riprap and gravel bedding might cause major inputs of atmospheric and waterborne suspended sediments to the environment. The location of the borrow area or areas would have a direct bearing on the extent of this input. The closer the area, obviously the better it would be for lessening the truck haul-induced sedimentation. The covering of the haul trucks would also lessen this input. During the covering operations for the creek, sedimentation control at the site might be difficult. Immediately compacting the impervious fill layer and armoring the streambed in stages might be necessary. If a topsoil cover is employed, the immediate seeding of this area with rapidly growing grasses would reduce sedimentary runoff to Bailey Bay and the James River.

During periods of high water and increased runoff, erosion of the partially completed project area would occur. This erosion would cause the greatest suspended sediment problems in the present construction area and in the marsh and swamp areas which have been stripped of vegetation. Some suspended sediment input via storm-water runoff would occur from the truck haul route and from the borrow area. Proper sedimentation control measures can be imposed on the borrow area as per existing State and Federal laws and guidelines which will minimize the susupended sediment load from this site. If the trucks are covered and the haul route peroidically cleaned, the runoff from the haul-route roads should not have significant short- or long-term environmental impacts. Runoff from and erosion of the site can be minimized by techniques discussed above; however, some erosion of the site will occur during high runoff periods. This runoff and subsequent sedimentation may have serious short-term and significant long-term impacts on the Bailey Bay system, depending on the extent of the expected recovery of the bay's ecosystem.

Construction of the spillway is not seen as adding any significant cumulative impacts to this alternative. Construction of the spillway before filling may prevent some sedimentary input to Bailey Bay during periods of high runoff and streamflow. This prevention of sedimentation could occur if the spillway is designed to form a retention pond as the streamflow increases.

Many of the lesser impacts of Alternative 4 for Gravelly Run also apply to this alternative.

Alternatives 9 and 10 were also not considered. While the impacts of 9 and 10 were the same as in Alternative 8, the conduits and concrete channel of the former added additional project costs without increasing the usefulness in controlling the Kepone-contaminated areas.

Alternative 11 involves the dredging of 2,200,000 cubic yards (1,682,000 cubic meters) from an area of 410 acres (166 ha). The area will first be cleared of trees and large shrubs, and the stumps and contaminated sediments will be removed by dragline dredge.

The removal of 2 to 3 feet (0.6 to 1 meter) of overlying earth and sediments will completely destroy the wetlands in this area. Included will be 345 acres (139.6 ha) of wooded swamp and 74 acres (30.0 ha) of marsh. The elevation of the land remaining may be suitable for the development of low marsh. Backfilling of the area would be necessary to allow the reconstruction of wooded swamp areas.

The removal of this area may have a net adverse or beneficial effect on the associated James River and terrestial ecosystems. This relatively simplistic statement is made because the present lack of information on the cycling of pollutants in the Bailey Creek ecosystems prevents the determination of this impact.

Dragline dredging may cause the sediment load to Bailey Creek to increase substantially, especially during periods of high runoff. The contaminant-laden suspended materials may have a debilitating effect on the Bailey Bay and James River biota. The use of silt screens and control of the dredging technique may lessen the input of these materials to the bay and river system. Dredging of the Bailey Bay area by a more efficient method after the Bailey Creek work has been completed would remove most of the sedimentation from the creek dredging that had occurred.

A haul road will be built from the dredging area to the disposal area. The construction of the road at the edge of the cleared area would add little additional environmetal impact to the proposed action.

Air pollutant emissions from this operation will not be large enough to have any significant short- or long-term effects on the area's air quality.

Dredging the creek and regrowth or reconstruction of the marsh may allow the development of habitat suitable for aquatic and terrestrial organisms in this creek. The continued runoff and leaching of pollutants from the upland areas may slow or stop this development. This negative effect would depend on the effect these organic and inorganic chemicals have on organisms which would use the reconstituted area as habitat.

Alternative 12 requires the construction of a dam 600 feet (183 meters) upstream of the Route 156 bridge on Bailey Creek and diverting the runoff around the Kepone-contaminated area. Two diversion routes are discussed.

The major impacts from this alternative would occur at the dam construction site and in Chappel Creek, the receiving watershed for one of the diversion routes.

Construction of the dam and spillway may cause excessive noise near some Hopewell and Prince George County residences. The haul route may also cause the disruption of traffic patterns as well as dust and noise problems. Covering the trucks and operating only during daylight hours will minimize this impact.

The loss of habitat involved with the dam and spillway sites may have some minor short- and long-term impacts, but the proximity of the site to populated areas may have already decreased its value as habitat.

The diversion flow to Chappell Creek may have significant impact on that system. Increased stream heights during high runoff peroids may cause long-term alteration of the creek's ecosystem. Pollutant loads to the creek would increase due to the storm-water runoff and sewage treatment plant effluent from Fort Lee and other populated areas, and roads. Depending on the nutrient and BOD assimilation capacity of Chappel Creek, Tar Bay may also be adversely affected by this diversion.

The diversion to Bailey Bay in conjunction with a cessation of the pollutant outflow from the lower reach of Bailey Creek will have a net beneficial impact on the Bailey Bay-James River environment, although it may not be as beneficial as the treatment of all flow from Bailey Creek (Alternative 7).

Flows in excess of the 100-year frequency would overtop the spillway and drain through the lower reach of Bailey Creek to Bailey Bay. Preparation of a riprapped flow channel below the spillway may lessen the physical impact of this flow. Minor short-term and no long-term impacts are foreseen from this overflow.

The dredging of Bailey Bay (Alternative 13) to a disposal area located in the southeast portion of the bay would probably have net beneficial environmental impacts. The beneficial effects would accrue if the removed polluted material is completely isolated from the environment.

Although large numbers of juvenile anadromous fish were observed in this area during field investigations, the lack of benthic organisms in samples from the bay indicate that the area is probably not extensively used for feeding. Dredging of the area at times of the year when these fish populations and spawning are at minimum should have minor short-term and no long-term effects on them. Uncovering a clean substrate in the bay may allow the development of benthic communities suitable for the reestablishment of this portion of the James River ecosystem. Effluents from the Regional Sewage Treatment Plant will have an impact on this area unless the outfall inside the mouth of Gravelly Run is relocated.

The short duration of this alternative (3 to 4 months) and utilization of a relatively low turbidity dredging method, coupled with treatment of the effluent, will also minimize the impacts of construction.

Alternatives 14 and 16 require the construction of a levee from Jordan Point to a location 1 mile (1.6 km) east of City Point.

While the levee would have relatively little apparent long-term impact on the environment from construction, the impacts of this barrier in Bailey Bay would be significant.

Short-term impacts from construction would probably be limited to those caused by suspended sediment introduction. Most of the sedimentation would occur during the placement of the hydraulic fill material. Correct use of silt screens and prompt riprapping of the levee's outer slope may cut suspended sediment loads to levels which can be tolerated by any nearby benthic organisms. Even if suspended and bed load sedimentation do reach lethal levels, the low concentrations of benthos in this area would not cause their loss of benthos to have any great long-term impacts on the river ecosystem. If this loss occurs in the inclosed portion of the bay, its impact may be overshadowed by the more serious impacts of this alternative on water quality and the marshes and thereby it will be insignificant by comparison.

Inside the levee, in the inclosed portion of the bay, the nutrient-laden waters and sediments will cause the area to rapidly become eutropic. Wide fluctuations in dissolved oxygen and pH will occur on daily cycles due mainly to algal photosynthetic activity.

Wind will also be a significant factor in controlling dissolved oxygen in the bay because it is so shallow. Even if the outfall of the Regional Sewage Treatment Plant is moved outside this levee, the input to Bailey Creek from overland runoff may be enough to keep the system permanently eutrophic.

The treatment of the outflow from the leveed area will serve to insulate the James River ecosystem from the inclosed polluted materials. Some "leakage" to the James River system will occur from terrestrial cycling of these pollutants and the overflow of the inclosed waters over the levee's spillway on the average of once every 100 years. Impacts from terrestrial uptake cannot be addressed at this time due to a lack of information. Spillway overflows will probably have significant short-term effects on the nearby aquatic environment, but the volume of overflow will be lost in the James River's floodflows at the same time, thereby being diluted to a concentration which will have little long-term impact when compared to the materials being carried by the James River's floodwaters.

The use of this area for a dredged material disposal area (Alternative 16) would have the beneficial impacts of removing pollutants in the dredged sediments from the riverine ecosystem. Sedimentation due to dredging operations would also be reduced over the present open-water disposal areas. Other than the yet to be resolved problem of terrestrial uptake, there does not seem to be a major increase in the environmental impacts of Alternative 16 over those of Alternative 14.

Alternatives 15 and 17 are considered combinations of alterantives 2, 7, and 13 (for 15) and alternatives 6, 11, and 13 (for 17). The cumulative impacts of these alternatives are the same as for plans G and U respectively and are briefly discussed in the "Combinations of Alternatives" part of this section.

The environmental impacts of the Alternatives are summarized in table B-12.

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Table B-12 SUMMARY ENVIRONMENTAL IMPACT MATRIX: KEPONE FEASIBILITY STUDY

Alternative no. and description	Type of possible impact										
	Social	Land use	Archeological historical (Data needed)	Wetlands	Estuarine Bottom	Upland wooded and agricultural	Pollutant mobilization	Air quality	Water quality	Ecological systems	Borrow or disposal areas
1 Gravelly Run Dam	None expected	Some disruption at Continental Can during flooding; logging truck access stopped	No known impact	Flooded during high runoff to 13.1(m.s.l.) No tide	Minor impact	Dam site area lost; Also spillway area	Reduced by dam and treatment works	Minor effect during construction	Enhanced by treatment works; sedimentation during construction	Tidal flooding eliminated; Character of area changed; Input to James lost	Little impact due to relatively small amount of material
2 Gravelly Run Dam w/diversion to Bailey Cr	None expected	None expected	None expected	Same as 1	Minor impact	Low value woods lost at dam site and spillway and diversion route	Not reduced but controlled for other treatment	Minor during construction	No change in WQ sedimentation during construction	Same as 1 plus additional runoff to Bailey Cr	Same as 1
3 Cover Gravelly Run bottom and construct spillway	None expected	None expected	Areas covered; excavation still possible	Wetlands destroyed; Possible to rebuild some in run	Minor impact	No loss due to construction or operation	Sediment leaching and movement controlled; Runoff not affected	Suspended particulates from earth moving operation	Reduction of leaching from bottom; Affected by stormwater runoff	Loss of wetlands; Clean upland meadow may develop	Sedimentation; Loss of habitat; Social impact due to truck haul
4 and 5 not considered											
6 Dredge Gravelly Run to disposal area; Treat effluent	None expected	None expected	Some impact at disposal area and treatment plant site	Wetlands destroyed can be rebuilt in place	Bottom area permanently covered by disposal area	Loss due to dredged material haul road	Some possible from dredging; Little from treated disposal effluent	Minor impact from equipment; odor; some hydrocarbon emissions	Turbidity from dredging; Little pollution from disposal area	Removal of some marsh and swamps	Site unspecified
7 Bailey Cr; Dam at mouth and treat runoff	None expected	None expected	Possible impact from dam site	Tidal influence blocked; Character of wetlands changed; Trees may be flooded	Bottom area decreased	Dam site spillway and treatment plant site lost	Decreased to aquatic environment; Unknown to upland environment	Temporary impact fr construction machinery	Improvement over present state; Reduction of inputs to Bailey Bay	Wetlands and marshes degraded; Possible replacements	Minor impact due to small amount of material
8 Cover Bailey Cr Bed to 5' m.s.l. and construct spillway	None expected	No conflict with current plans	Possible sites covered can be excavated later; minor impact at construction pts	Wetlands destroyed; Some rehabilitation may be possible	Bottom area decreased	No impact anticipated fr construction or operation	Decreased or stopped fr creek bed; Runoff not affected	Suspended particulates fr earth moving operation	Reduction of leaching and bed load introduction of pollutants to James; Runoff not affected	Possible long-term reduction of pollutants in regional food chain; Loss of wetland habitat	Sedimentation at site; Loss of habitat; social impacts due to truck haul
9 and 10 not considered											
11 Dredge Bailey Cr to disposal	Disposal area may have impact;	Conflict may arise in choice of borrow	Sites lost if present	Wetlands destroyed	Bottom area decreased	Loss due to dredged material haul road	Turbidity with attached pollutants possible	Odor possible; Hydrocarbon emissions	Turbidity depending on dredge used	Wetlands destroyed; Possible reclamation of	Truck haul to west side of Bailey Bay

11 Dredge Bailey Cr to disposal area; Treat effluent	Disposal area may have impact; Dredging minor impacts	Conflict may arise in choice of borrow area	Sites lost if present	Wetlands destroyed	Bottom area decreased	Loss due to dredged material haul road	Turbidity with attached pollutants possible during dredging; Little from disposal area	Odor possible; Hydrocarbon emissions from sediments	Turbidity depending on dredge used	Wetlands destroyed; Possible reclamation of low marsh; Pollutant cycling stopped	Truck haul to west side of Bailey Bay
12 Dam Bailey Cr upstream of Rt. 156 bridge; Divert runoff to James River at Bailey Bay	Evacuation of 25 structures	Some of pool area precluded from development	No known sites disturbed	Wetland areas above bridge may be altered by periodic inurdation	None lost; Above tidal influence	Loss at dam site	Little effect except to reduce lower creek erosion	Short-term effects during construction	Sedimentation during construction; No change during operation except to hold storm water	Some effect on wetlands otherwise little change	Required for dam construction material; Some short-term effects if commercial area
12A Diversion to Chappell Cr (move info needed on Chappell Cr)	Same as 12 but also along pipeline R.O.W.	Same as 12	Same as above except study of R.O.W. may be needed also	Same as above	Same as above	Same additional loss along Rt. 646 pipeline route	Same as above	Same as above	Same as above	Diverted water may have impact on Chappell Creek watershed	Same as above
13 Dredge all of Bailey Bay and pump into a disposal area	Possible visual from disposal area	Minor impact	No known sites disturbed	Little impact	Up to 1 meter of low productivity bottom removed; Cleaner area remains	Little impact	Minimized by dredging method and control measures; Minor impact over present condition	Little impact from dredging operations; Some impact fr levee construction	Impacts from turbidity; Little impact fr spoil area due to treatment	Benthos destroyed; Polluted material removed; Pollutant cycling lessened	Disposal area on west side of bay; Little impact if pollutants stabilized
14 Dike Bailey Creek and treat runoff from the inclosed area	Possible visual impacts	Little impact	Minor impact except along dike construction corridor	Cut off from tidal influence; Major long-term impact	Cut off from tides and fish and benthos migration	Little effect	Leaching and runoff to James River stopped by treatment	Minor impact during construction	Impounded water may become eutrophic	Cycling of pollutants fr diked area will continue; Aquatic system degraded	Disposal of James River channel sediments w/treatment will have little added impact
15 Dam Bailey Cr, dredge bay, and use Cr as a disposal area; Dam Gravelly Run and divert to Bailey Cr; Treat effluent	See Alternatives 2, 7, and 13										
16 Included in alternative 14											
17 Construct levee in Bailey Bay along east shore	See Alternatives 6, 11, and 13										

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THE ENVIRONMENTAL IMPACTS OF COMBINATIONS OF ALTERNATIVES

Each of the alternatives discussed has the potential of being included in an overall solution for the Kepone contamination problem in the project area. The proposed combinations of the remaining alternatives are indicated in table 24 of the engineering report. Alternatives 3, 4, 9, 10, and 18 have been eliminated from further consideration due to engineering problems or additional costs over other alternatives offering the same level of problem solution.

Table 24 of the engineering report covers the various combinations of the alternatives considered. For the purpose of environmental impact determination, the various dam heights discussed for a single alternative (such as 7A-7G) are treated as one. The dredging of Bailey Bay (13 and 13A) is also treated as one alternative, even though the volume removed is almost doubled (2.1 to 3.3 million cubic meters, respectively) for Alternative 13A. This results in 15 environmentally distinct plans for the control of Kepone in Gravelly Run, Bailey Creek, and Bailey Bay. These are plans A, C, E, F, G, I, K, M, O, P, Q, S, U, V, and W.

The cumulative impacts from the construction of any of the combinations does not appear to be any greater than the sum of the impacts of the component alternatives. The sequence of construction of the components may reduce the impacts from construction. For example, dredging Bailey Bay last in any plan would presumably remove the contaminated sediments released during any measures in Bailey Creek and Gravelly Run. Dredging Bailey Bay first would recontaminate the "cleaner" bay substrate with materials suspended by construction activities in the creek and run.

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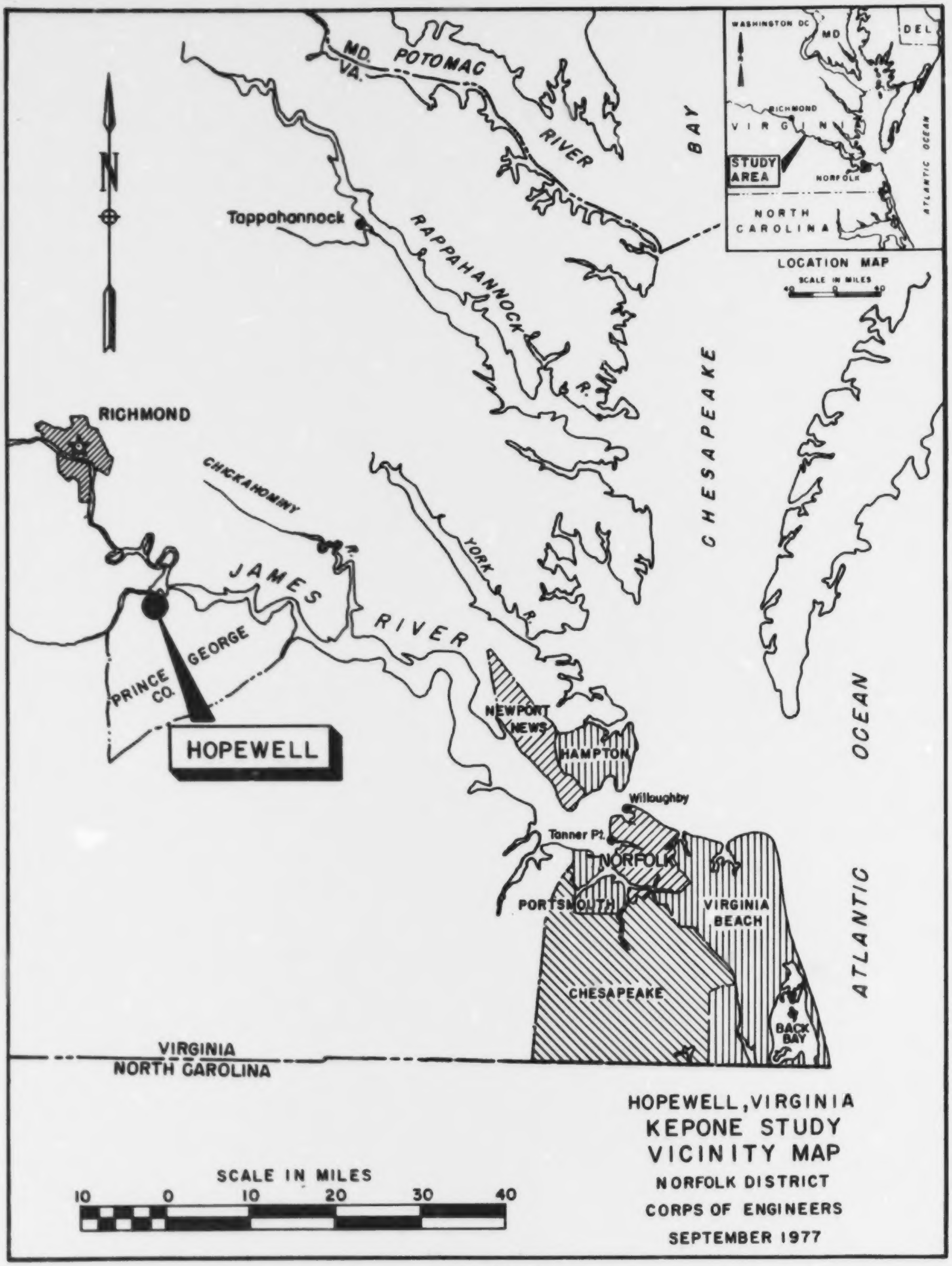
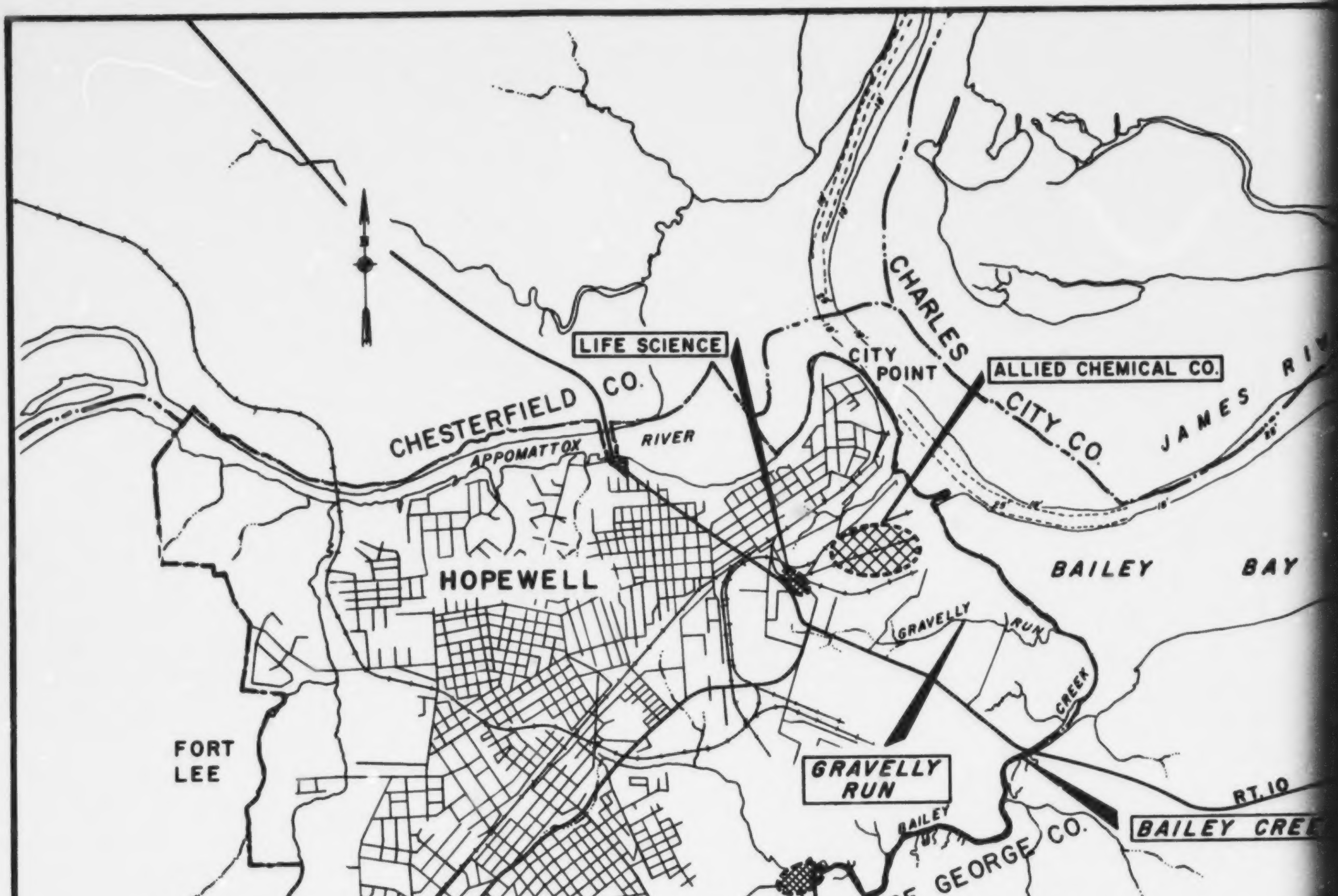


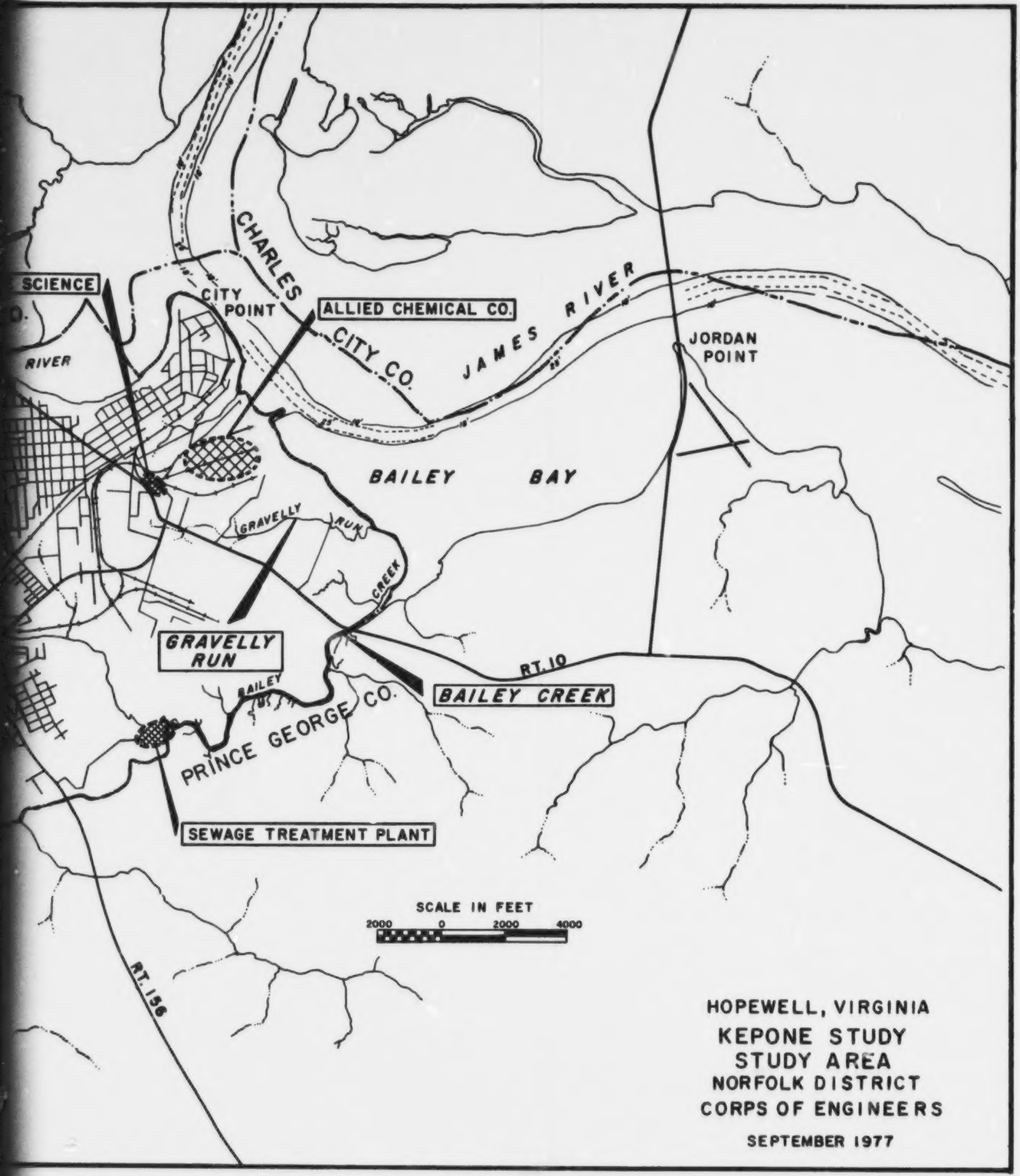
WASHINGTON DC
MD
DEL
RICHMOND
VIRGINIA
STUDY AREA
NORFOLK
NORTH CAROLINA
ATLANTIC OCEAN
LOCATION MAP
SCALE IN MILES
40 0 40
MD.
VA.
POTOMAC
RIVER
BAY
N
Tappahannock
RAPPAHANNOCK R.
CHESAPEAKE
RICHMOND
CHICKAHOMINY R.
YORK R.
JAMES RIVER
PRINCE GEORGE CO.
HOPEWELL
NEWPORT NEWS
HAMPTON
Willoughby
Tanner Pt.
NORFOLK
PORTSMOUTH
VIRGINIA BEACH
CHESAPEAKE
BACK BAY
ATLANTIC
OCEAN
VIRGINIA
NORTH CAROLINA
SCALE IN MILES
10 0 10 20 30 40

HOPEWELL, VIRGINIA
KEPONE STUDY
VICINITY MAP
NORFOLK DISTRICT
CORPS OF ENGINEERS
SEPTEMBER 1977

PLATE B-1


LIFE SCIENCE
CITY POINT
ALLIED CHEMICAL CO.
CHARLES CITY CO.
JAMES RIV
CHESTERFIELD CO.
APPOMATTOX RIVER
HOPEWELL
BAILEY BAY
GRAVELLY RUN
GRAVELLY RUN
CREEK
FORT LEE
RT. 10
BAILEY CREE
BAILEY CR.
PRINCE GEORGE CO.
SEWAGE TREATMENT PLANT
SCALE IN FEET
2000
0
2000
4000
RT. 156

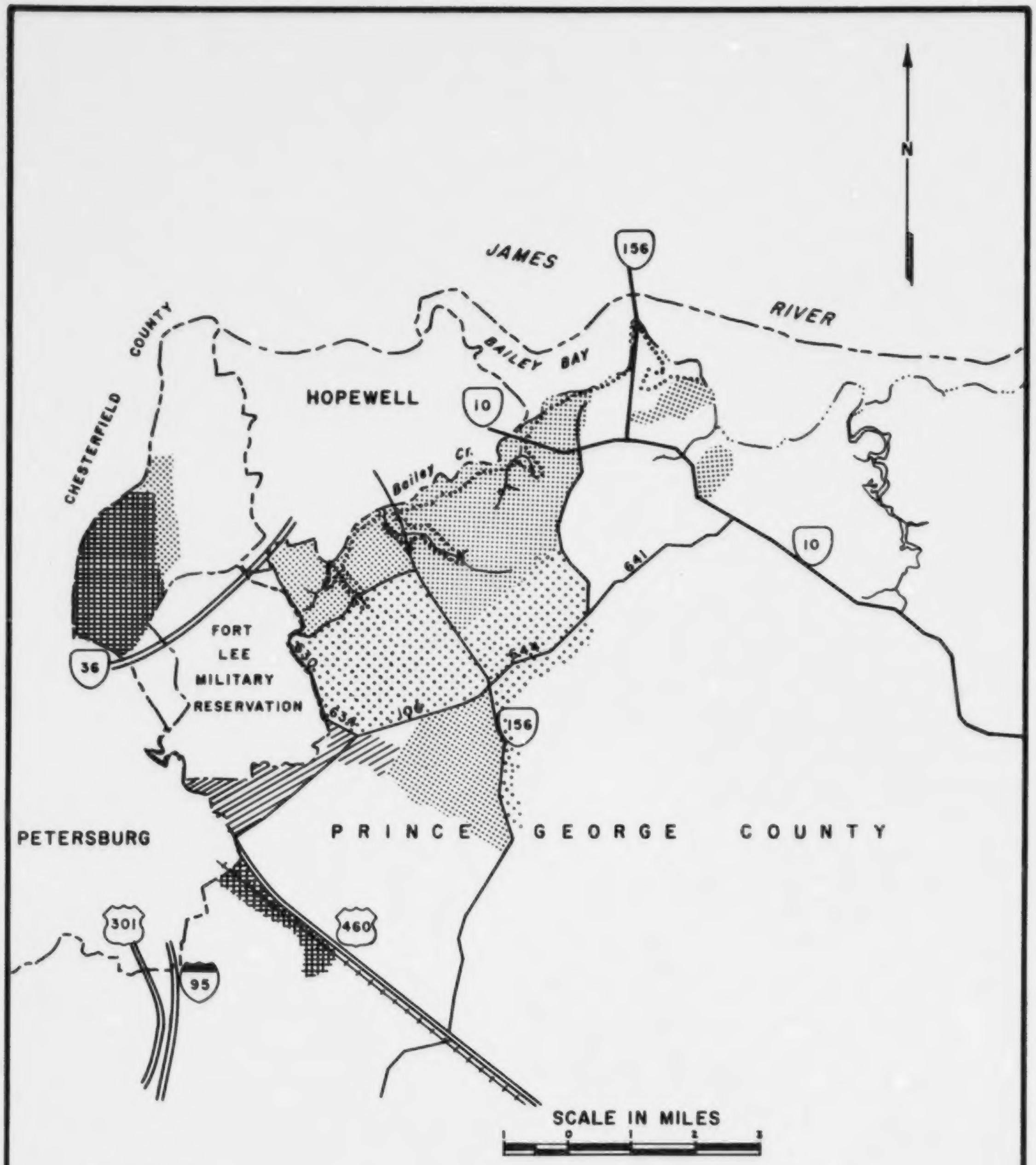
A


SCIENCE
O.
RIVER
CHARLES CITY CO.
CITY POINT
ALLIED CHEMICAL CO.
JAMES RIVER
JORDAN POINT
BAILEY BAY
GRAVELLY RUN
CREEK
GRAVELLY RUN
BAILEY CREEK
BAILEY
RT. 10
PRINCE GEORGE CO.
SEWAGE TREATMENT PLANT
SCALE IN FEET
2000
0
2000
4000
RT. 156

HOPEWELL, VIRGINIA
KEPONE STUDY
STUDY AREA
NORFOLK DISTRICT
CORPS OF ENGINEERS
SEPTEMBER 1977

B

PLATE B-2


N
JAMES
RIVER
156
CHESTERFIELD COUNTY
BAILEY BAY
HOPEWELL
10
Bailey Cr.
641
10
FORT
LEE
MILITARY
RESERVATION
36
630
634
106
648
156
PETERSBURG
PRINCE GEORGE COUNTY
301
460
95
SCALE IN MILES
1 0 1 2 3

LEGEND

░ SUBURBAN DEVELOPMENT -LOW DENSITY

▒ SUBURBAN DEVELOPMENT -MEDIUM DENSITY 1

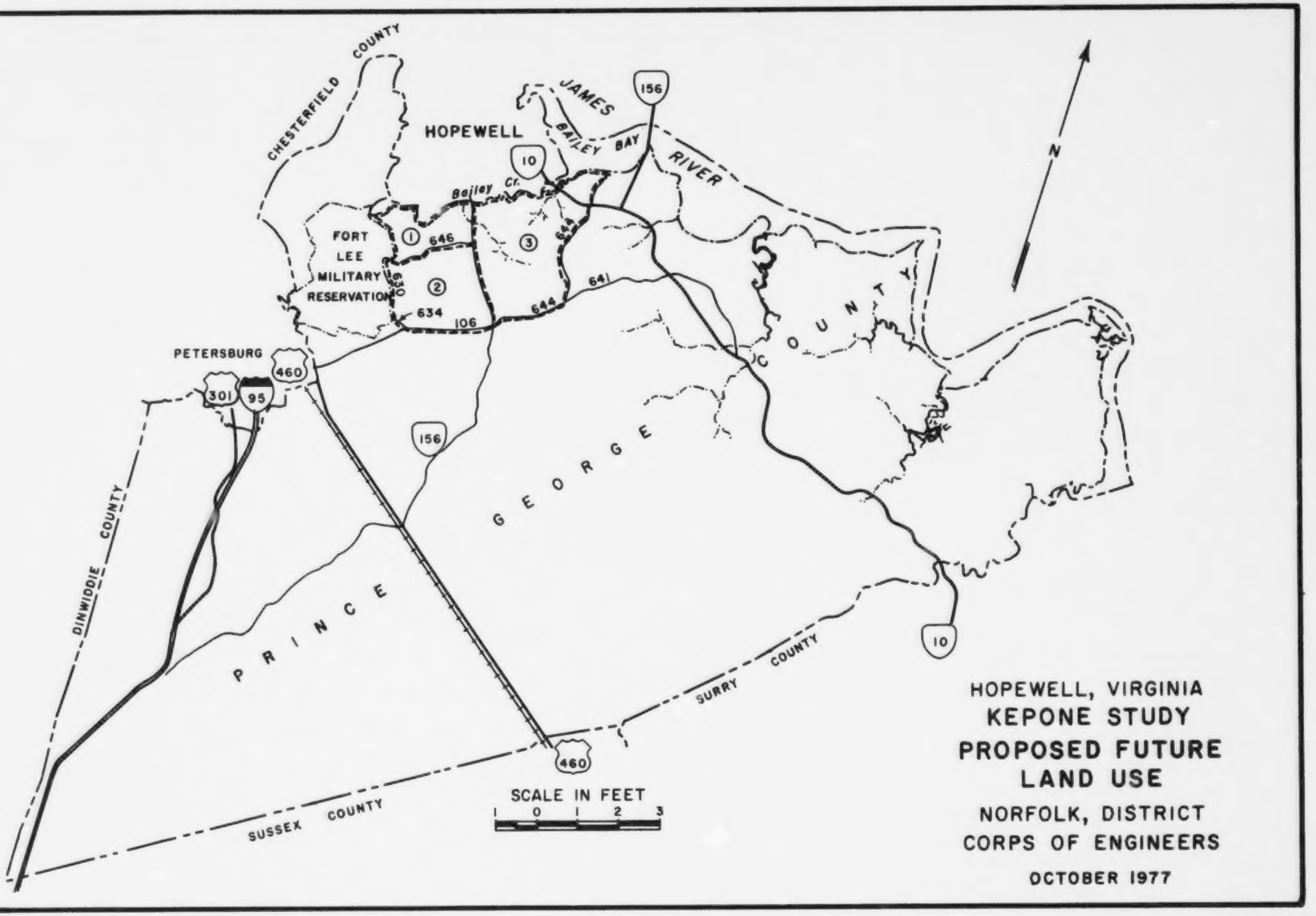
▨ SUBURBAN DEVELOPMENT -MEDIUM DENSITY 2

▓ INDUSTRIAL

┈┈┈ CRITICAL ENVIRONMENTAL AREA

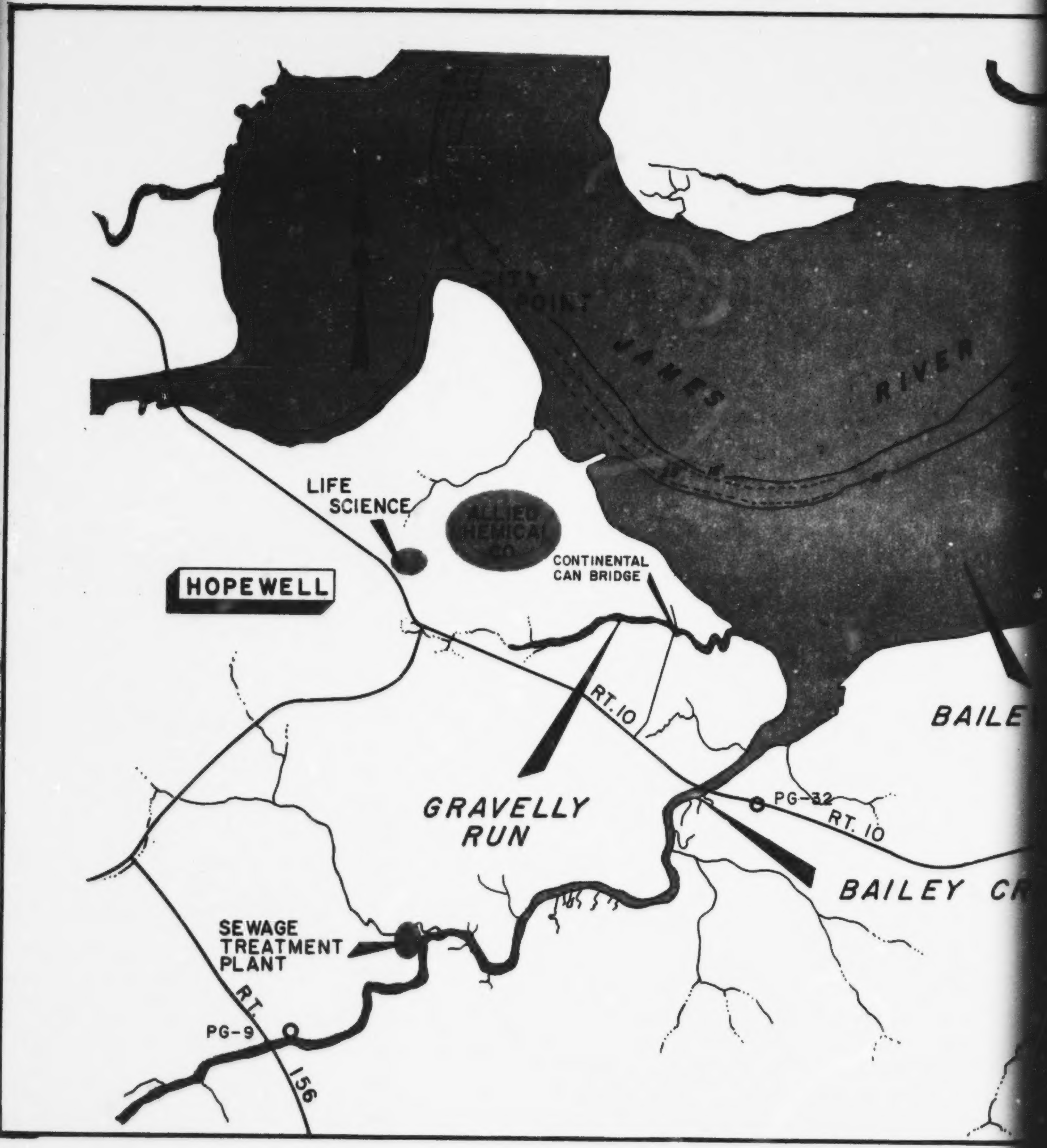
HOPEWELL, VIRGINIA
KEPONE STUDY
PROPOSED FUTURE
LAND USE
NORFOLK, DISTRICT
CORPS OF ENGINEERS
OCTOBER 1977

PLATE B-3

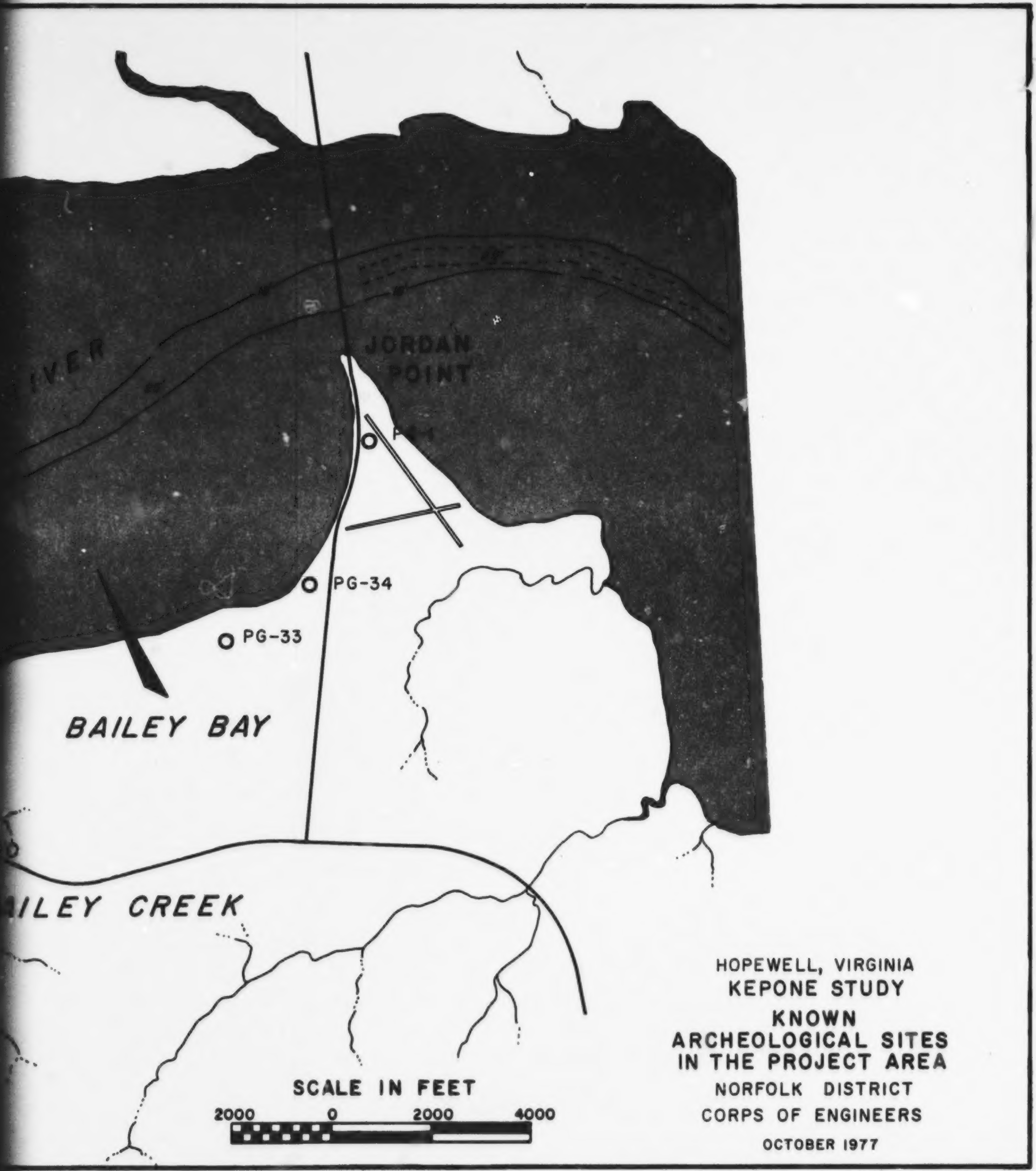

CHESTERFIELD COUNTY
HOPEWELL
JAMES
BAILEY BAY
RIVER
156
10
Bailey Cr.
FORT LEE MILITARY RESERVATION
1
646
2
630
634
106
3
644
641
PETERSBURG
460
301
95
156
COUNTY
PRINCE GEORGE
DINWIDDIE COUNTY
SURRY COUNTY
SUSSEX COUNTY
460
10
N
SCALE IN FEET
1 0 1 2 3

HOPEWELL, VIRGINIA
KEPONE STUDY
PROPOSED FUTURE
LAND USE
NORFOLK, DISTRICT
CORPS OF ENGINEERS
OCTOBER 1977

PLATE B-4

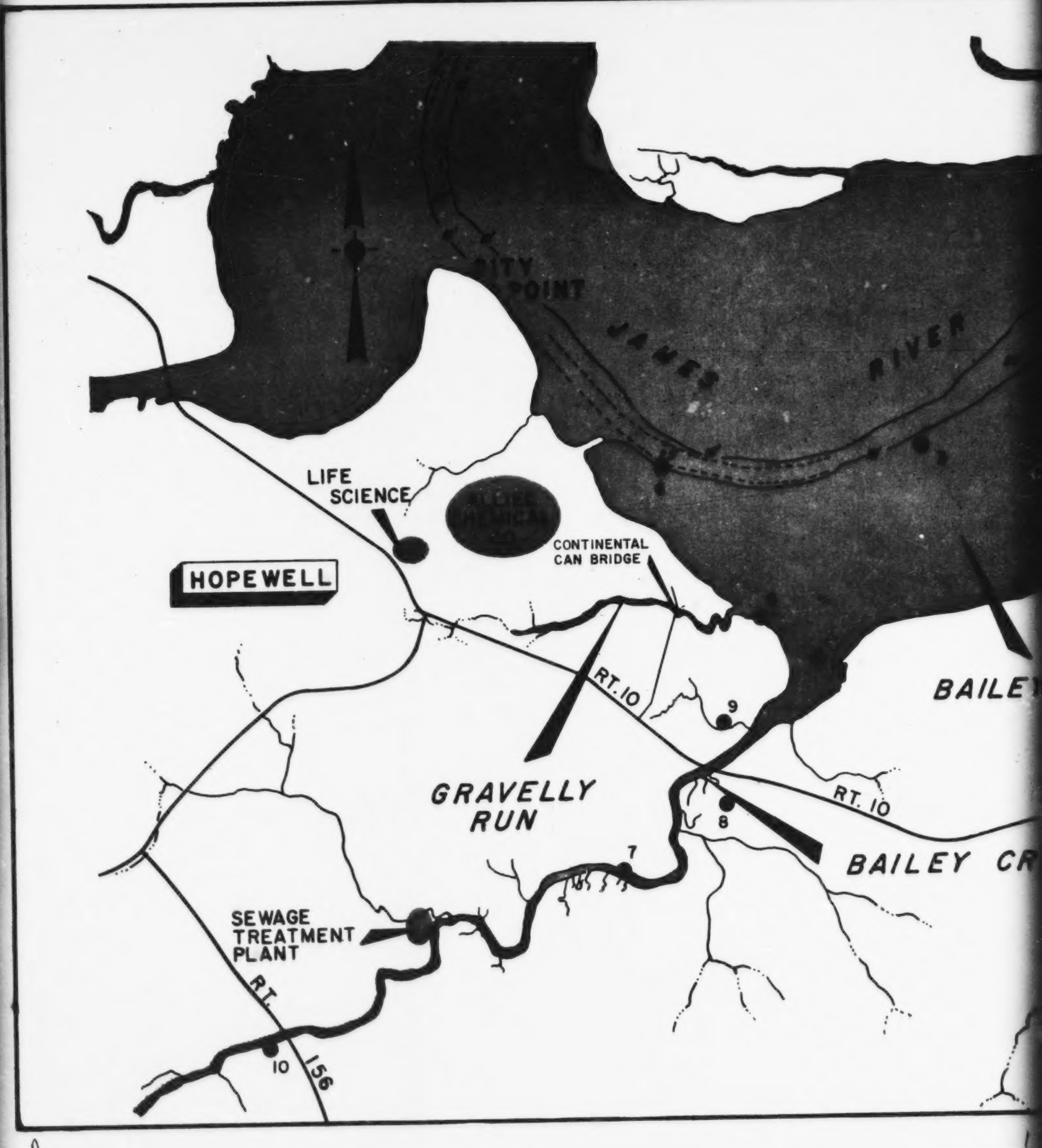

CITY POINT
JAMES RIVER
LIFE SCIENCE
ALLIED CHEMICAL CO.
HOPEWELL
CONTINENTAL CAN BRIDGE
RT. 10
BAILE
GRAVELLY RUN
PG-32
RT. 10
BAILEY CR
SEWAGE TREATMENT PLANT
RT. 156
PG-9

A

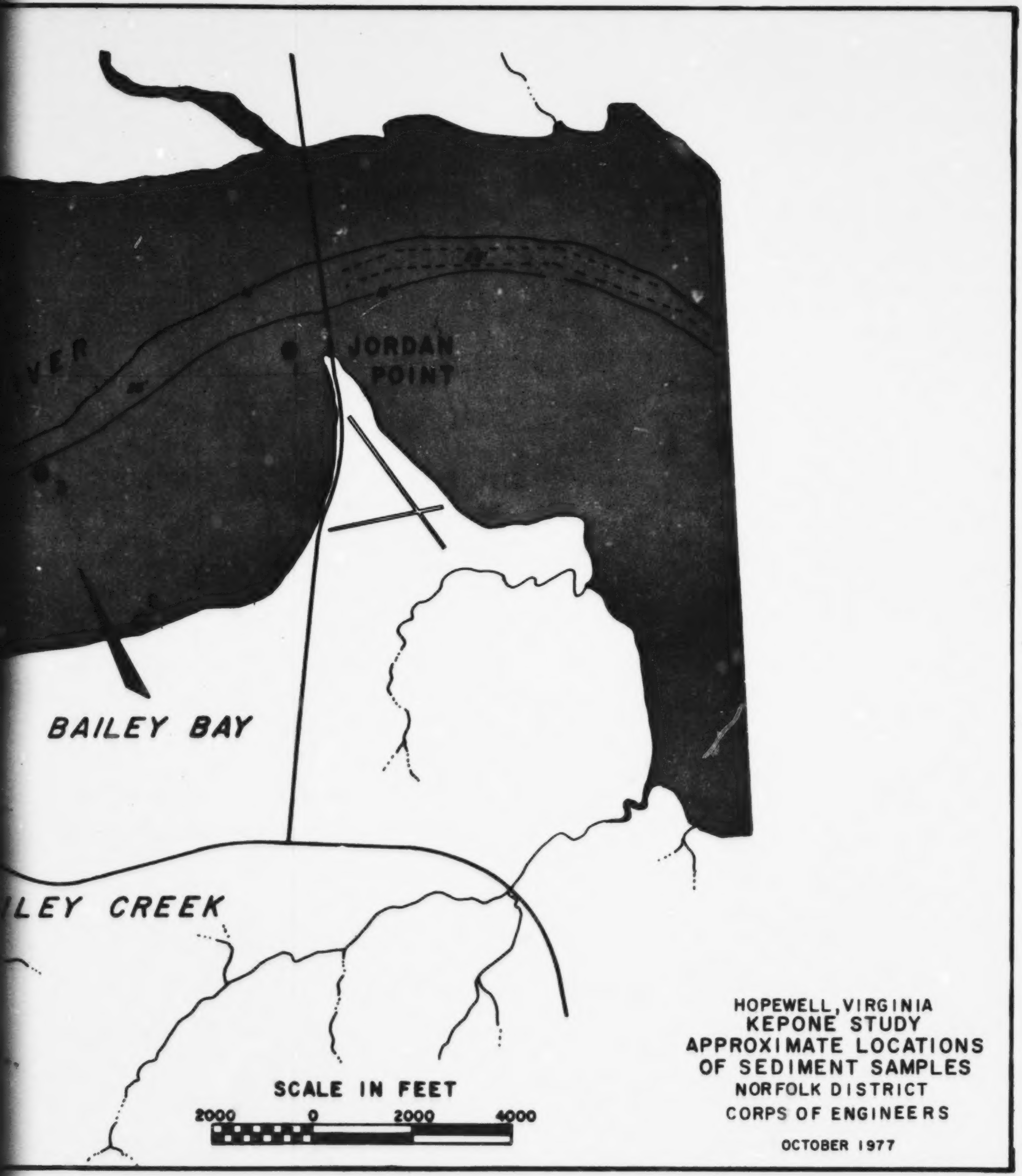

IVER
JORDAN POINT
PG-34
PG-33
BAILEY BAY
AILEY CREEK
SCALE IN FEET
2000
0
2000
4000

HOPEWELL, VIRGINIA
KEPONE STUDY
KNOWN
ARCHEOLOGICAL SITES
IN THE PROJECT AREA
NORFOLK DISTRICT
CORPS OF ENGINEERS
OCTOBER 1977

1 407< B **PLATE B-5**


CITY POINT
JAMES RIVER
LIFE SCIENCE
ALLIED CHEMICAL CO.
HOPEWELL
CONTINENTAL CAN BRIDGE
RT. 10
BAILEY
9
GRAVELLY RUN
RT. 10
8
BAILEY CR
7
SEWAGE TREATMENT PLANT
RT. 156
10

A


VER
JORDAN POINT
BAILEY BAY
ILEY CREEK
SCALE IN FEET
2000
0
2000
4000

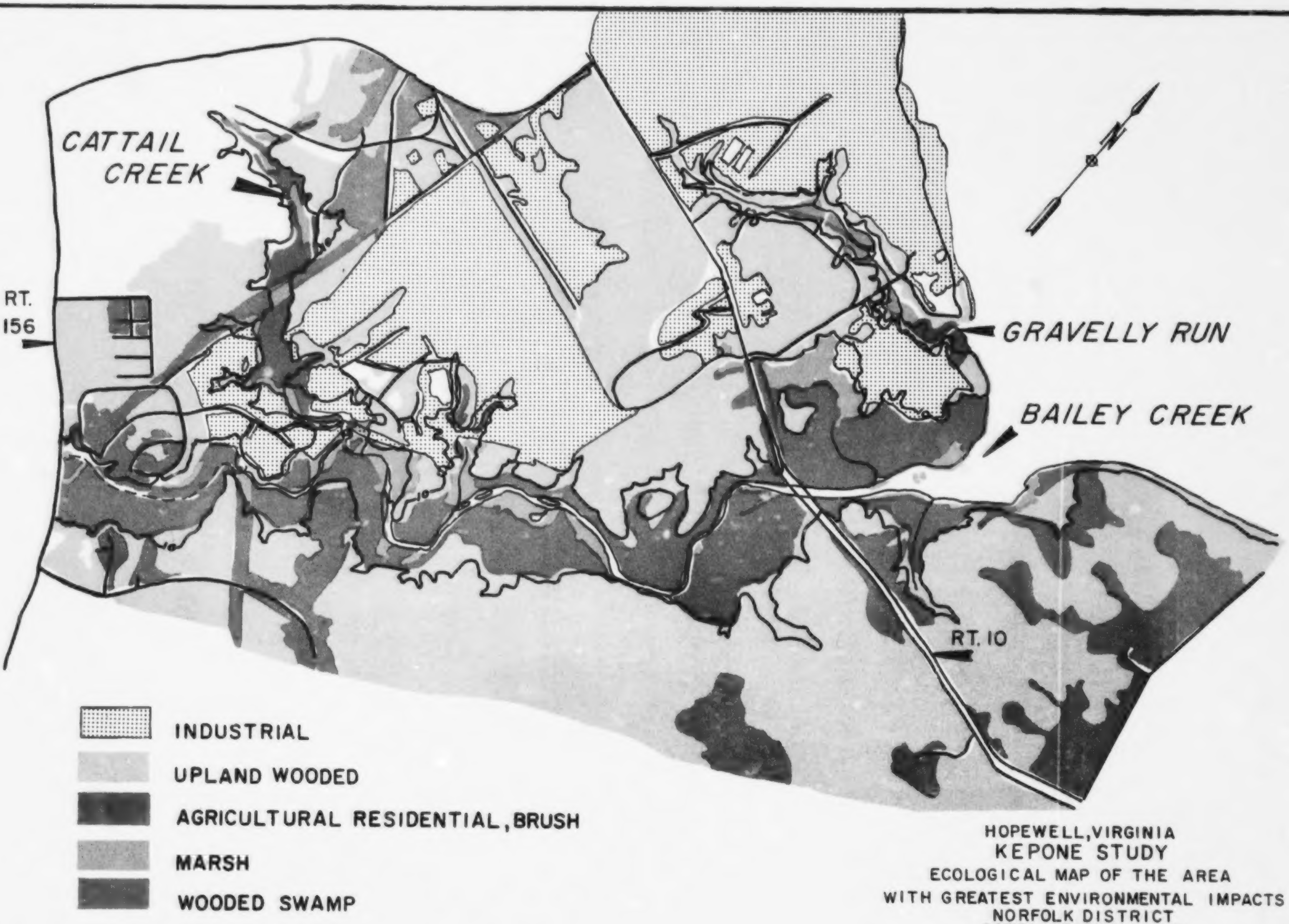
HOPEWELL, VIRGINIA
KEPONE STUDY
APPROXIMATE LOCATIONS
OF SEDIMENT SAMPLES
NORFOLK DISTRICT
CORPS OF ENGINEERS

OCTOBER 1977

B

1

408<


CATTAIL CREEK
RT. 156
GRAVELLY RUN
BAILEY CREEK
RT. 10
INDUSTRIAL
UPLAND WOODED
AGRICULTURAL RESIDENTIAL, BRUSH
MARSH
WOODED SWAMP

HOPEWELL, VIRGINIA
KEPONE STUDY
ECOLOGICAL MAP OF THE AREA
WITH GREATEST ENVIRONMENTAL IMPACTS
NORFOLK DISTRICT
CORPS OF ENGINEERS
OCTOBER, 1977

PLATE B-7

SECTION C

COST ESTIMATES

SECTION C

COST ESTIMATES

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(CONT'D)

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INTRODUCTION

This section of the appendix contains detailed cost estimates for each of the original 18 alternatives presented in the main report. In addition, cost estimates are presented for Alternatives 2A, 7B, 7E, and the Bailey Bay disposal area. By using the detailed cost estimates for Alternatives 7, 7B, and 7E, a graph was developed for the height of the dam versus cost. Using this curve, cost estimates were obtained for Alternatives 7A, 7C, 7D, 7F, and 7G. All cost estimates are based on August 1977 prices and contain a contingency factor of 20 percent.

Table C-1. DETAILED COST ESTIMATE FOR ALTERNATIVE 1

Description	Estimated Quantity	Unit	Unit Cost	Cost($) Subtotal	Cost($) Total
EMBANKMENT					
Clearing & Grubbing	10	Acres	1,840.00	18,400	
Excavation	20,000	C.Y.	3.50	70,000	
Stream Diversion	1	Job	L.S.	11,500	
Impervious Fill	46,000	C.Y.	2.30	105,800	
Riprap	5,000	C.Y.	34.50	172,500	
Bedding	2,500	C.Y.	16.10	40,300	
Filter Cloth	8,000	S.Y.	2.30	18,400	
Seeding (Including Top Soil)	3,600	S.Y.	1.40	5,000	
SUBTOTAL				441,900	
CONTINGENCIES 20%				88,400	
TOTAL EMBANKMENT					530,300
SLURRY TRENCH					
Excavation	1,500	C.Y.	4.60	6,900	
Slurry Mixture (Bentonite, Sand, & Gravel)	1,500	C.Y.	11.50	17,300	
SUBTOTAL				24,200	
CONTINGENCIES 20%				4,800	
TOTAL SLURRY TRENCH					29,000
EMERGENCY SPILLWAY					
Clearing & Grubbing	3	Acres	1,840.00	5,500	
Excavation	8,400	C.Y.	2.90	24,400	
Concrete Liner (1' Thick Reinforced Concrete)	900	C.Y.	161.00	144,900	
SUBTOTAL				174,800	
CONTINGENCIES 20%				35,000	
TOTAL EMERGENCY SPILLWAY					209,800
MISCELLANEOUS ITEMS					
Temp. Haul Road	1	Job	L.S.	57,500	
Reservoir Clearing	72	Acres	300.00	21,600	
SUBTOTAL				79,100	
CONTINGENCIES 20%				15,800	
TOTAL MISCELLANEOUS ITEMS					94,900
LAND AND EASEMENTS					
Elevation 5' m.s.l. and Below	30	Acres	1,000.00	30,000	
Elevation Above 5' m.s.l. to Take line - 21.4' m.s.l.	42	Acres	3,000.00	126,000	
SUBTOTAL				156,000	
CONTINGENCIES 20%				31,200	
TOTAL LAND AND EASEMENTS					187,200
ENGINEERING AND DESIGN @ 12%					126,100
SUPERVISION AND ADMINISTRATION @ 8%					84,100

Seeding (Including Top Soil)	3,600	S.Y.	1.40	5,000	
SUBTOTAL				441,900	
CONTINGENCIES 20%				88,400	
TOTAL EMBANKMENT					530,300
SLURRY TRENCH					
Excavation	1,500	C.Y.	4.60	6,900	
Slurry Mixture (Bentonite, Sand, & Gravel)	1,500	C.Y.	11.50	17,300	
SUBTOTAL				24,200	
CONTINGENCIES 20%				4,800	
TOTAL SLURRY TRENCH					29,000
EMERGENCY SPILLWAY					
Clearing & Grubbing	3	Acres	1,840.00	5,500	
Excavation	8,400	C.Y.	2.90	24,400	
Concrete Liner (1' Thick Reinforced Concrete)	900	C.Y.	161.00	144,900	
SUBTOTAL				174,800	
CONTINGENCIES 20%				35,000	
TOTAL EMERGENCY SPILLWAY					209,800
MISCELLANEOUS ITEMS					
Temp. Haul Road	1	Job	L.S.	57,500	
Reservoir Clearing	72	Acres	300.00	21,600	
SUBTOTAL				79,100	
CONTINGENCIES 20%				15,800	
TOTAL MISCELLANEOUS ITEMS					94,900
LAND AND EASEMENTS					
Elevation 5' m.s.l. and Below	30	Acres	1,000.00	30,000	
Elevation Above 5' m.s.l. to Take line - 21.4' m.s.l.	42	Acres	3,000.00	126,000	
SUBTOTAL				156,000	
CONTINGENCIES 20%				31,200	
TOTAL LAND AND EASEMENTS					187,200
ENGINEERING AND DESIGN @ 12%					126,100
SUPERVISION AND ADMINISTRATION @ 8%					84,100
TOTAL COST					1,261,400
TOTAL COST ROUNDED					1,261,000

414<

B

P

Table C-2. DETAILED COST ESTIMATE FOR ALTERNATIVE 2

Description	Estimated Quantity	Unit	Unit Cost	Cost ($) Subtotal	Cost ($) Total
EMBANKMENT					
Clearing & Grubbing	9	Acres	1,840.00	16,600	
Excavation	10,000	C.Y.	3.50	35,000	
Impervious Fill	17,000	C.Y.	2.30	39,100	
Riprap	3,400	C.Y.	34.50	117,300	
Bedding	1,700	C.Y.	16.10	27,400	
Filter Cloth	5,600	S.Y.	2.30	12,900	
Seeding	700	S.Y.	1.40	1,000	
Stream Diversion	1	Job	L.S.	11,500	
SUBTOTAL				260,800	
CONTINGENCIES 20%				52,200	
TOTAL EMBANKMENT					313,000
EMERGENCY SPILLWAY					
Concrete Liner (1' Thick Reinforced Concrete)	200	C.Y.	161.00	32,200	
SUBTOTAL				32,200	
CONTINGENCIES 20%				6,400	
TOTAL EMERGENCY SPILLWAY					38,600
MISCELLANEOUS ITEMS					
Temp. Haul Road	1	Job	L.S.	57,500	
Reservoir Clearing	57	Acres	300.00	17,100	
SUBTOTAL				74,600	
CONTINGENCIES 20%				14,900	
TOTAL EMERGENCY SPILLWAY					89,500
LAND AND EASEMENTS					
Conduit Easement	2	Acres	1,000.00	2,000	
Elevation 5' m.s.l. and Below	30	Acres	1,000.00	30,000	
Elevation Above 5' m.s.l. to Take Line of 16.4 m.s.l.	27	Acres	3,000.00	81,000	
SUBTOTAL				113,000	
CONTINGENCIES 20%				22,600	
TOTAL LAND AND EASEMENTS					135,600
DIVERSION CONDUIT					
Clearing and Grubbing	2	Acres	1,840.00	3,700	
Excavation	42,500	C.Y.	3.50	148,800	
Backfill	37,000	C.Y.	2.90	107,300	
Asbestos-Bonded, Paved Invert 10 Gauge Corrugated Pipe	2,000	L.F.	195.50	391,000	
Riprap	42	C.Y.	34.50	1,400	
SUBTOTAL				652,200	
CONTINGENCIES 20%				130,400	
TOTAL DIVERSION CONDUIT					782.600
[illegible]					163,100

					313,000
EMERGENCY SPILLWAY					
Concrete Liner (1' Thick Reinforced Concrete)	200	C.Y.	161.00	32,200	
SUBTOTAL				32,200	
CONTINGENCIES 20%				6,400	
TOTAL EMERGENCY SPILLWAY					38,600
MISCELLANEOUS ITEMS					
Temp. Haul Road	1	Job	L.S.	57,500	
Reservoir Clearing	57	Acres	300.00	17,100	
SUBTOTAL				74,600	
CONTINGENCIES 20%				14,900	
TOTAL EMERGENCY SPILLWAY					89,500
LAND AND EASEMENTS					
Conduit Easement	2	Acres	1,000.00	2,000	
Elevation 5' m.s.l. and Below	30	Acres	1,000.00	30,000	
Elevation Above 5' m.s.l. to Take Line of 16.4 m.s.l.	27	Acres	3,000.00	81,000	
SUBTOTAL				113,000	
CONTINGENCIES 20%				22,600	
TOTAL LAND AND EASEMENTS					135,600
DIVERSION CONDUIT					
Clearing and Grubbing	2	Acres	1,840.00	3,700	
Excavation	42,500	C.Y.	3.50	148,800	
Backfill	37,000	C.Y.	2.90	107,300	
Asbestos-Bonded, Paved Invert 10 Gauge Corrugated Pipe	2,000	L.F.	195,50	391,000	
Riprap	42	C.Y.	34.50	1,400	
SUBTOTAL				652,200	
CONTINGENCIES 20%				130,400	
TOTAL DIVERSION CONDUIT					782,600
ENGINEERING AND DESIGN (12%)					163,100
SUPERVISION AND ADMINISTRATION (8%)					108,700
TOTAL COST					1,631,100
TOTAL COST ROUNDED					1,631,000

B

A

Table C-3. DETAILED COST ESTIMATE FOR ALTERNATIVE 2A

Description	Estimated Quantity	Unit	Unit Cost	Cost ($)	
				Subtotal	Total
EMBANKMENT					
Clearing and Grubbing	9	Acres	1,840.00	16,600	
Excavation	10,000	C.Y.	3.50	35,000	
Impervious Fill	17,000	C.Y.	2.30	39,100	
Riprap	3,400	C.Y.	34.50	117,300	
Bedding	1,700	C.Y.	16.10	27,400	
Filter Cloth	5,600	S.Y.	2.30	12,900	
Seeding	700	S.Y.	1.40	1,000	
Stream Diversion	1	Job	L.S.	11,500	
SUBTOTAL				260,800	
CONTINGENCIES 20%				52,200	
TOTAL EMBANKMENT					313,000
EMERGENCY SPILLWAY					
Concrete liner (1' Thick Reinforced Concrete)	200	C.Y.	161.00	32,200	
SUBTOTAL				32,200	
CONTINGENCIES 20%				6,400	
TOTAL EMERGENCY SPILLWAY					38,600
DIVERSION CONDUIT					
Clearing and Grubbing	2	Acres	1,840.00	3,700	
Excavation	42,500	C.Y.	3.50	148,800	
Backfill	37,000	C.Y.	2.90	107,300	
Steel Water Pipe	2,000	L.F.	195.50	391,000	
Riprap	42	C.Y.	34.50	1,400	
Pump Station	1	L.S.	-	4,500,000	
SUBTOTAL				5,152,200	
CONTINGENCIES 20%				1,030,400	
TOTAL DIVERSION CONDUIT					6,182,600
MISCELLANEOUS ITEMS					
Temp. Haul Road	1	Job	L.S.	57,500	
Reservoir Clearing	57	Acres	300.00	17,100	
SUBTOTAL				74,600	
CONTINGENCIES 20%				14,900	
TOTAL MISCELLANEOUS ITEMS					89,500
LAND AND EASEMENTS					
Conduit Easement	2	Acres	1,000.00	2,000	
Elevation 5' m.s.l. and Below	30	Acres	1,000.00	30,000	
Elevation Above 5' m.s.l. to Take Line of 16.4' m.s.l.	27	Acres	3,000.00	81,000	
SUBTOTAL				113,000	
CONTINGENCIES 20%				22,600	
TOTAL LAND AND EASEMENTS					135,600
ENGINEERING AND DESIGN @ 12%					811,100

SUBTOTAL					
CONTINGENCIES 20%				52,200	
TOTAL EMBANKMENT					313,000
EMERGENCY SPILLWAY					
Concrete liner (1' Thick Reinforced Concrete)	200	C.Y.	161.00	32,200	
SUBTOTAL				32,200	
CONTINGENCIES 20%				6,400	
TOTAL EMERGENCY SPILLWAY					38,600
DIVERSION CONDUIT					
Clearing and Grubbing	2	Acres	1,840.00	3,700	
Excavation	42,500	C.Y.	3.50	148,800	
Backfill	37,000	C.Y.	2.90	107,300	
Steel Water Pipe	2,000	L.F.	195.50	391,000	
Riprap	42	C.Y.	34.50	1,400	
Pump Station	1	L.S.	-	4,500,000	
SUBTOTAL				5,152,200	
CONTINGENCIES 20%				1,030,400	
TOTAL DIVERSION CONDUIT					6,182,600
MISCELLANEOUS ITEMS					
Temp. Haul Road	1	Job	L.S.	57,500	
Reservoir Clearing	57	Acres	300.00	17,100	
SUBTOTAL				74,600	
CONTINGENCIES 20%				14,900	
TOTAL MISCELLANEOUS ITEMS					89,500
LAND AND EASEMENTS					
Conduit Easement	2	Acres	1,000.00	2,000	
Elevation 5' m.s.l. and Below	30	Acres	1,000.00	30,000	
Elevation Above 5' m.s.l. to Take Line of 16.4' m.s.l.	27	Acres	3,000.00	81,000	
SUBTOTAL				113,000	
CONTINGENCIES 20%				22,600	
TOTAL LAND AND EASEMENTS					135,600
ENGINEERING AND DESIGN @ 12%					811,100
SUPERVISION AND ADMINISTRATION @ 8%					540,700
TOTAL COST					8,111,100
TOTAL COST ROUNDED					8,111,000

B

Table C-4. DETAILED COST ESTIMATE FOR ALTERNATIVE 3

Description	Estimated Quantity	Unit	Unit Cost	Cost ($) Subtotal	Cost ($) Total
CONTROL STRUCTURE					
Excavation	620	C.Y.	6.90	4,300	
Backfill	620	C.Y.	5.80	3,600	
40' x 14" x 14" Reinforced Concrete Piles	16	Ea.	57.50	900	
9'2" x 1'5" Reinforced Concrete Planks	98	Ea.	34.50	3,400	
4'4" x 1'5" Reinforced Concrete Planks	6	Ea.	23.00	100	
Filter Cloth	187	S.Y.	2.30	400	
Riprap	67	C.Y.	34.50	2,300	
Bedding	48	C.Y.	16.10	800	
SUBTOTAL				15,800	
CONTINGENCIES 20%				3,200	
TOTAL CONTROL STRUCTURE					19,000
3-FOOT CLAY COVER					
Clearing (Woods & Swamp)	19.6	Acres	1,840.00	36,100	
Clay Layer (3')	145,000	C.Y.	2.00	290,000	
Riprap	7,000	C.Y.	34.50	241,500	
Gravel Bedding	7,000	C.Y.	16.10	112,700	
Typar Filter Cloth	144,444	S.F.	1.20	173,300	
Top Soil	24,000	C.Y.	6.00	144,000	
Seeding	30	Acres	500.00	15,000	
Land and Easements	30	Acres	1,000.00	30,000	
SUBTOTAL				1,042,600	
CONTINGENCIES 20%				208,500	
TOTAL 3' CLAY COVER					1,251.100
ENGINEERING AND DESIGN @ 12%					152,400
SUPERVISION AND ADMINISTRATION @ 8%					101,600
TOTAL COST					1,524,100
TOTAL COST ROUNDED					1,524,000

Table C-5. DETAILED COST ESTIMATE FOR ALTERNATIVE 6

Description	Estimated Quantity	Unit	Unit Cost	Cost ($) Subtotal	Cost ($) Total
SITE WORK					
Clearing	20	Acres	3,000.00	60,000	
Ramps	2	Ea.	55,000.00	110,000	
Roadwork	1	Job	L.S.	17,000	
SUBTOTAL				187,000	
CONTINGENCIES 20%				37,400	
TOTAL SITE WORK COST					224,400
EXCAVATION					
Haul Roads	7,040	C.Y.	15.00	105,600	
Dragline	148,588	C.Y.	1.00	148,600	
SUBTOTAL				254,200	
CONTINGENCIES 20%				50,800	
TOTAL EXCAVATION COST					305,000
DISPOSAL (TRUCK HAUL)	152,240	C.Y.	1.50	228,400	
SUBTOTAL				228,400	
CONTINGENCIES 20%				45,700	
TOTAL DISPOSAL COST					274,100
MOBILIZATION AND DEMOBILIZATION	1	Job	L.S.	13,000	
SUBTOTAL				13,000	
CONTINGENCIES 20%				2,600	
TOTAL MOBILIZATION AND DEMOBILIZATION COST					15,600
LAND AND EASEMENTS	30	Acres	1,000.00	30,000	
SUBTOTAL				30,000	
CONTINGENCIES 20%				6,000	
TOTAL LAND AND EASEMENTS COST					36,000
ENGINEERING AND DESIGN @ 12%					
SUPERVISION AND ADMINISTRATION @ 8%					68,400
TOTAL COST					1,026,100
TOTAL COST ROUNDED					1,026,000

Table C-6. DETAILED COST ESTIMATE FOR ALTERNATIVE 7

Description	Estimated Quantity	Unit	Unit Cost	Cost ($) Subtotal	Cost ($) Total
EMBANKMENT					
Clearing and Grubbing	6	Acres	1,840.00	11,000	
Excavation (Muck Removal)	103,000	C.Y.	4.60	473,800	
Hydraulic Fill	525,000	C.Y.	2.10	1,102,500	
Impervious Cutoff					
Excavation	14,100	C.Y.	3.50	49,400	
Bentonite Slurry	14,100	C.Y.	11.50	162,200	
Riprap (2' Thick)	16,000	C.Y.	34.50	552,000	
Bedding (1' Thick)	8,000	C.Y.	16.10	128,800	
Filter Cloth	24,000	S.Y.	2.30	55,200	
Gravel Crest (1' Thick)	1,400	C.Y.	16.10	22,500	
Seeding	7,600	S.Y.	1.40	10,600	
Stream Diversion	1	Job	L.S.	17,000	
Haul Road	1	Job	L.S.	115,000	
SUBTOTAL				2,700,000	
CONTINGENCIES 20%				540,000	
TOTAL EMBANKMENT					3,240,000
EMERGENCY SPILLWAY					
Excavation	7,800	C.Y.	2.90	22,600	
Concrete Liner (1' Reinforced)	1,200	C.Y.	161.00	193,200	
SUBTOTAL				215,800	
CONTINGENCIES 20%				43,200	
TOTAL EMERGENCY SPILLWAY					259,000
RESERVOIR CLEARING					
Clearing	1,060	Acres	300.00	318,000	
SUBTOTAL				318,000	
CONTINGENCIES 20%				63,600	
TOTAL RESERVOIR CLEARING					381,600
BRIDGE REPLACEMENT					
Replace East Bound RT-10-156 Bridge					
Remove Bridge	1	Job	L.S.	70,000	
New Bridge	1	Job	L.S.	300,000	
Roadway and Approach	1	Job	L.S.	300,000	
SUBTOTAL				670,000	
CONTINGENCIES 25%				167,500	
TOTAL BRIDGE REPLACEMENT					837,500
LAND AND EASEMENTS					
Elevation 5' m.s.l. and Below	511	Acres	1,000.00	511,000	
Elevation Above 5' m.s.l. to Take Line of 28' m.s.l.	549	Acres	3,000.00	1,647,000	
Residential relocations	7	Ea.	40,000.00	280,000	
SUBTOTAL				2,438,000	
CONTINGENCIES 20%				487,600	

SUBTOTAL				2,700,000	
CONTINGENCIES 20%				540,000	
TOTAL EMBANKMENT					3,240,000
EMERGENCY SPILLWAY					
Excavation	7,800	C.Y.	2.90	22,600	
Concrete Liner (1' Reinforced)	1,200	C.Y.	161.00	193,200	
SUBTOTAL				215,800	
CONTINGENCIES 20%				43,200	
TOTAL EMERGENCY SPILLWAY					259,000
RESERVOIR CLEARING					
Clearing	1,060	Acres	300.00	318,000	
SUBTOTAL				318,000	
CONTINGENCIES 20%				63,600	
TOTAL RESERVOIR CLEARING					381,600
BRIDGE REPLACEMENT					
Replace East Bound RT-10-156 Bridge					
Remove Bridge	1	Job	L.S.	70,000	
New Bridge	1	Job	L.S.	300,000	
Roadway and Approach	1	Job	L.S.	300,000	
SUBTOTAL				670,000	
CONTINGENCIES 25%				167,500	
TOTAL BRIDGE REPLACEMENT					837,500
LAND AND EASEMENTS					
Elevation 5' m.s.l. and Below	511	Acres	1,000.00	511,000	
Elevation Above 5' m.s.l. to Take Line of 28' m.s.l.	549	Acres	3,000.00	1,647,000	
Residential relocations	7	Ea.	40,000.00	280,000	
SUBTOTAL				2,438,000	
CONTINGENCIES 20%				487,600	
TOTAL LAND AND EASEMENTS					2,925,600
ENGINEERING AND DESIGN 12%					917,200
SUPERVISION AND ADMINISTRATION 8%					611,400
TOTAL COST					9,171,600
TOTAL COST ROUNDED 1/					9,172,000

1/ Includes replacement cost of only 1 Bridge (eastbound) on Rt. 10-156.

Table C-7. DETAILED COST ESTIMATE FOR ALTERNATIVE 7B

Description	Estimated Quantity	Unit	Unit Cost	Cost ($) Subtotal	Cost ($) Total
EMBANKMENT					
Clearing and Grubbing	6	Acres	1,840.00	11,000	
Excavation (Muck Removal)	94,000	C.Y.	4.60	432,400	
Hydraulic Fill	375,000	C.Y.	2.10	787,500	
Impervious Cutoff					
Excavation	12,200	C.Y.	3.50	42,700	
Bentonite Slurry	12,200	C.Y.	11.50	140,300	
Riprap (2' Thick)	14,000	C.Y.	34.50	483,000	
Bedding (1' Thick)	7,000	C.Y.	16.10	112,700	
Filter Cloth	22,000	S.Y.	2.30	50,600	
Gravel Crest (1' Thick)	1,400	C.Y.	16.10	22,500	
Seeding	5,600	S.Y.	1.40	7,800	
Stream Diversion	1	Job	L.S.	17,000	
Haul Road	1	Job	L.S.	115,000	
SUBTOTAL				2,222,500	
CONTINGENCIES 20%				444,500	
TOTAL EMBANKMENT					2,667,000
EMERGENCY SPILLWAY					
Excavation	2,600	C.Y.	2.90	7,500	
Concrete Liner (1' Reinforced)	500	C.Y.	161.00	80,500	
SUBTOTAL				88,000	
CONTINGENCIES 20%				17,600	
TOTAL EMERGENCY SPILLWAY					105,600
RESERVOIR CLEARING					
Clearing	760	Acres	300.00	228,000	
SUBTOTAL				228,000	
CONTINGENCIES 20%				45,600	
TOTAL RESERVOIR CLEARING					273,600
LAND AND EASEMENTS					
Elevation 5' m.s.l. and below	511	Acres	1,000.00	511,000	
Elevation Above 5' m.s.l. to Take Line of 21.4' m.s.l.	249	Acres	3,000.00	747,000	
Residential Relocation	7	Ea.	40,000.00	280,000	
SUBTOTAL				1,538,000	
CONTINGENCIES 20%				307,600	
TOTAL LAND AND EASEMENTS					1,845,600
ENGINEERING AND DESIGN @ 12%					587,000
SUPERVISION AND ADMINISTRATION @ 8%					391,300

Bedding (1' Thick)	7,000	C.Y.	16.10	112,700	
Filter Cloth	22,000	S.Y.	2.30	50,600	
Gravel Crest (1' Thick)	1,400	C.Y.	16.10	22,500	
Seeding	5,600	S.Y.	1.40	7,800	
Stream Diversion	1	Job	L.S.	17,000	
Haul Road	1	Job	L.S.	115,000	
SUBTOTAL				2,222,500	
CONTINGENCIES 20%				444,500	
TOTAL EMBANKMENT					2,667,000
EMERGENCY SPILLWAY					
Excavation	2,600	C.Y.	2.90	7,500	
Concrete Liner (1' Reinforced)	500	C.Y.	161.00	80,500	
SUBTOTAL				88,000	
CONTINGENCIES 20%				17,600	
TOTAL EMERGENCY SPILLWAY					105,600
RESERVOIR CLEARING					
Clearing	760	Acres	300.00	228,000	
SUBTOTAL				228,000	
CONTINGENCIES 20%				45,600	
TOTAL RESERVOIR CLEARING					273,600
LAND AND EASEMENTS					
Elevation 5' m.s.l. and below	511	Acres	1,000.00	511,000	
Elevation Above 5' m.s.l. to Take Line of 21.4' m.s.l.	249	Acres	3,000.00	747,000	
Residential Relocation	7	Ea.	40,000.00	280,000	
SUBTOTAL				1,538,000	
CONTINGENCIES 20%				307,600	
TOTAL LAND AND EASEMENTS					1,845,600
ENGINEERING AND DESIGN @ 12%					587,000
SUPERVISION AND ADMINISTRATION @ 8%					391,300
TOTAL COST					5,870,100
TOTAL COST ROUNDED					5,870,000

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Table C-8. DETAILED COST ESTIMATE FOR ALTERNATIVE 7E

Description	Estimated Quantity	Unit	Unit Cost	Cost($) Subtotal	Cost($) Total
EMBANKMENT					
Clearing & Grabbing	6	Acres	1,840.00	11,000	
Excavation (Muck Removal)	106,700	C.Y.	4.60	490,800	
Hydraulic Fill	557,000	C.Y.	2.10	1,169,700	
Impervious Cutoff					
Excavation	14,600	C.Y.	3.50	51,100	
Bentonite Slurry	14,600	C.Y.	11.50	167,900	
Riprap	16,700	C.Y.	34.50	576,200	
Bedding (1' Thick)	8,400	C.Y.	16.10	135,200	
Filter Cloth	28,300	S.Y.	2.30	65,100	
Gravel Crest	1,400	C.Y.	16.10	22,500	
Seeding	7,600	S.Y.	1.40	10,600	
Stream Diversion	1	Job	L.S.	17,000	
Haul Road	1	Job	L.S.	115,000	
SUBTOTAL				2,832,100	
CONTINGENCIES 20%				566,400	
TOTAL EMBANKMENT					3,398,500
EMERGENCY SPILLWAY					
Excavation	7,800	C.Y.	2.90	22,600	
Concrete Liner (1' Reinforced Concrete)	1,200	C.Y.	161.00	193,200	
SUBTOTAL				215,800	
CONTINGENCIES 20%				43,200	
TOTAL EMERGENCY SPILLWAY					259,000
RESERVOIR CLEARING					
Clearing	1,110	Acres	300.00	333,000	
SUBTOTAL				333,000	
CONTINGENCIES 20%				66,600	
TOTAL RESERVOIR CLEARING					399,600
ROUTE 10-156 BRIDGES					
Remove Bridge (985')	1	Job	L.S.	290,000	
Remove Bridge (220')	1	Job	L.S.	70,000	
New Bridge (985')	1	Job	L.S.	1,227,000	
New Bridge (220')	1	Job	L.S.	300,000	
New Roadway	1	Job	L.S.	600,000	
SUBTOTAL				2,487,000	
CONTINGENCIES 25%				621,800	
TOTAL ROUTE 10-156 BRIDGES					3,108,800
LAND AND EASEMENTS					
Elevation 5' & Below	511	Acres	1,000.00	511,000	
Elevation Above 5' m.s.l. to Take Line of 29.5' m.s.l.	599	Acres	3,000.00	1,797,000	
Relocations - Residential	7	Ea.	40,000.00	280,000	
SUBTOTAL				2,588,000	
CONTINGENCIES 20%				517,600	

SUBTOTAL				2,832,100	
CONTINGENCIES 20%				566,400	
TOTAL EMBANKMENT					3,398,500
EMERGENCY SPILLWAY					
Excavation	7,800	C.Y.	2.90	22,600	
Concrete Liner (1' Reinforced Concrete)	1,200	C.Y.	161.00	193,200	
SUBTOTAL				215,800	
CONTINGENCIES 20%				43,200	
TOTAL EMERGENCY SPILLWAY					259,000
RESERVOIR CLEARING					
Clearing	1,110	Acres	300.00	333,000	
SUBTOTAL				333,000	
CONTINGENCIES 20%				66,600	
TOTAL RESERVOIR CLEARING					399,600
ROUTE 10-156 BRIDGES					
Remove Bridge (985')	1	Job	L.S.	290,000	
Remove Bridge (220')	1	Job	L.S.	70,000	
New Bridge (985')	1	Job	L.S.	1,227,000	
New Bridge (220')	1	Job	L.S.	300,000	
New Roadway	1	Job	L.S.	600,000	
SUBTOTAL				2,487,000	
CONTINGENCIES 25%				621,800	
TOTAL ROUTE 10-156 BRIDGES					3,108,800
LAND AND EASEMENTS					
Elevation 5' & Below	511	Acres	1,000.00	511,000	
Elevation Above 5' m.s.l. to Take Line of 29.5' m.s.l.	599	Acres	3,000.00	1,797,000	
Relocations - Residential	7	Ea.	40,000.00	280,000	
SUBTOTAL				2,588,000	
CONTINGENCIES 20%				517,600	
TOTAL LAND AND EASEMENTS					3,105,600
ENGINEERING AND DESIGN @ 12%					1,232,600
SUPERVISION AND ADMINISTRATION @ 8%					821,700
TOTAL COST					12,325,800
TOTAL COST ROUNDED					12,326,000

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Table C-9. DETAILED COST ESTIMATE FOR ALTERNATIVE 8

Description	Estimated Quantity	Unit	Unit Cost	Cost ($) Subtotal	Cost ($) Total
CONTROL STRUCTURE					
Excavation	13,500	C.Y.	6.90	93,200	
Backfill	13,500	C.Y.	5.80	78,300	
35' X 14" X 14" Reinforced Concrete Piles	88	Ea.	51.80	4,600	
9'2" X 1'5" Reinforced Concrete Planks	860	Ea.	34.50	29,700	
4'4" X 1'5" Reinforced Concrete Panels	6	Ea.	23.00	100	
Filter Cloth	1,100	S.Y.	2.30	2,500	
Riprap	320	C.Y.	34.50	11,000	
Bedding	275	C.Y.	16.10	4,400	
SUBTOTAL				223,800	
CONTINGENCIES 20%				44,800	
TOTAL CONTROL STRUCTURE					268,600
3-FOOT CLAY COVER					
Clearing	410	Acres	1,840.00	754,400	
Clay Layer (3')	2,246,000	C.Y.	2.00	4,492,000	
Riprap	78,000	C.Y.	34.50	2,691,000	
Gravel Bedding	78,000	C.Y.	16.10	1,255,800	
Typar Filter Cloth	2,246,000	S.Y.	1.15	2,582,900	
Top Soil	374,000	C.Y.	6.00	2,244,000	
Seeding	464	Acres	500.00	232,000	
SUBTOTAL				14,252,100	
CONTINGENCIES 20%				2,850,400	
TOTAL 3-FOOT CLAY COVER					17,102,500
ENGINEERING AND DESIGN @ 12%					2,084,500
SUPERVISION AND ADMINISTRATION @ 8%					1,389,700
TOTAL COST					20,845,300
TOTAL COST ROUNDED					20,845,000

Table C-10. DETAILED COST ESTIMATE FOR ALTERNATIVE 11

Description	Estimated Quantity	Unit	Unit Cost	Cost ($) Subtotal	Cost ($) Total
SITE WORK					
Clearing	410	Acres	3,000.00	1,230,000	
Ramps	12	Ea.	55,000.00	660,000	
Roadwork	1	Job	L.S.	275,000	
SUBTOTAL				2,165,000	
CONTINGENCIES 20%				433,000	
TOTAL SITE WORK COST					2,598,000
EXCAVATION					
Haul Roads	65,218	C.Y.	15.00	978,300	
Dragline	3,587,892	C.Y.	1.00	3,587,900	
SUBTOTAL				4,566,200	
CONTINGENCIES 20%				913,200	
TOTAL EXCAVATION COST					5,479,400
DISPOSAL (TRUCK HAUL)	2,548,138	C.Y.	1.50	3,822,200	
SUBTOTAL				3,822,200	
CONTINGENCIES 20%				764,400	
TOTAL DISPOSAL COST					4,586,600
MOBILIZATION AND DEMOBILIZATION	1	Job	L.S.	52,000	
SUBTOTAL				52,000	
CONTINGENCIES 20%				10,400	
TOTAL MOBILIZATION AND DEMOLITION COST					62,400
LAND AND EASEMENTS	513	Acres	1,000	513,000	
SUBTOTAL				513,000	
CONTINGENCIES 20%				102,600	
TOTAL LAND AND EASEMENTS COST					615,600
ENGINEERING AND DESIGN @ 12%					1,601,000
SUPERVISION AND ADMINISTRATION @ 8%					1,067,400
TOTAL COST					16,010,400
TOTAL COST ROUNDED					16,010,000

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Table C-11. DETAILED COST ESTIMATE FOR ALTERNATIVE 12

Description	Estimated Quantity	Unit	Unit Cost	Cost($) Subtotal	Cost($) Total
EMBANKMENT					
Clearing & Grubbing	22	Acres	1,840.00	40,500	
Excavation	38,000	C.Y.	3.50	133,000	
Stream Diversion	1	Job	L.S.	12,000	
Impervious Fill	264,000	C.Y.	2.30	607,200	
Riprap	10,000	C.Y.	34.50	345,000	
Bedding	6,000	C.Y.	16.10	96,600	
Filter Cloth	19,000	S.Y.	2.30	43,700	
Seeding	21,000	S.Y.	1.40	29,400	
Haul Road	1	Job	L.S.	58,000	
SUBTOTAL				1,365,400	
CONTINGENCIES 20%				273,100	
TOTAL EMBANKMENT					1,638,500
RELIEF DRAINS					
Excavation	200	C.Y.	4.60	900	
Gravel Filter	200	C.Y.	16.10	3,200	
6" Perforated P.V.C.	300	L.F.	5.80	1,700	
Concrete Ditch	50	C.Y.	172.50	8,600	
SUBTOTAL				14,400	
CONTINGENCIES 20%				2,900	
TOTAL RELIEF DRAINS					17,300
EMERGENCY SPILLWAY					
Clearing & Grubbing	10	Acres	1,840.00	18,400	
Excavation	134,000	C.Y.	2.90	388,600	
Concrete Liner (1' Reinforced Concrete Liner)	3,700	C.Y.	161.00	595,700	
SUBTOTAL				1,002,700	
CONTINGENCIES 20%				200,500	
TOTAL EMERGENCY SPILLWAY					1,203,200
RESERVOIR CLEARING					
Clearing	405	Acres	300.00	121,500	
SUBTOTAL				121,500	
CONTINGENCIES 20%				24,300	
TOTAL RESERVOIR CLEARING					145,800
PIPELINE					
Excavation	312,000	C.Y.	1.70	530,400	
Backfill	210,000	C.Y.	1.20	252,000	
Pavement Patch	4,400	S.F.	9.20	40,500	
Welded Steel Pipe	34,000	L.F.	250.00	8,500,000	
Asbestos Felt Wrap	572,000	S.F.	0.30	171,600	
Clearing & Grubbing	30	Acres	1,840.00	55,200	
Seeding	30	Acres	500.00	15,000	
SUBTOTAL				9,564,700	
CONTINGENCIES 20%				1,912,900	
TOTAL PIPELINE					11,477,600

Clearing	405	Acres	300.00	121,500	
SUBTOTAL				121,500	
CONTINGENCIES 20%				24,300	
TOTAL RESERVOIR CLEARING					145,800
PIPELINE					
Excavation	312,000	C.Y.	1.70	530,400	
Backfill	210,000	C.Y.	1.20	252,000	
Pavement Patch	4,400	S.F.	9.20	40,500	
Welded Steel Pipe	34,000	L.F.	250.00	8,500,000	
Asbestos Felt Wrap	572,000	S.F.	0.30	171,600	
Clearing & Grubbing	30	Acres	1,840.00	55,200	
Seeding	30	Acres	500.00	15,000	
SUBTOTAL				9,564,700	
CONTINGENCIES 20%				1,912,900	
TOTAL PIPELINE					11,477,600
SUPPORTS					
Concrete, Cradles	400	Ea.	2,300.00	920,000	
14" X 60' Concrete Piles	1,600	Ea.	23.00	36,800	
1-1/8" Anchor Bolts	3,200	Ea.	6.90	22,100	
Steel Strap	17,000	L.F.	1.20	20,400	
SUBTOTAL				999,300	
CONTINGENCIES 20%				199,900	1,199,200
TOTAL SUPPORTS					
INLET AND OUTLET WORKS					
Concrete Intake Structure	1	L.S.	9,200.00	9,200	
Concrete Spillway	1	L.S.	9,200.00	9,200	
SUBTOTAL				18,400	
CONTINGENCIES 20%				3,700	
TOTAL INLET & OUTLET WORKS					22,100
LAND AND EASEMENTS					
Acquisition	425	Acres	3,000.00	1,275,000	
Relocations - Homes	25	Ea.	40,000.00	1,000,000	
SUBTOTAL				2,275,000	
CONTINGENCIES 20%				455,000	
TOTAL LAND & EASEMENTS					2,730,000
ENGINEERING AND DESIGN @ 12%					2,212,000
SUPERVISION AND ADMINISTRATION @ 8%					1,474,700
TOTAL COST					22,120,400
TOTAL COST ROUNDED					22,120,000

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Table C-12. DETAILED COST ESTIMATE FOR ALTERNATIVE 12A

Description	Estimated Quantity	Unit	Unit Cost	Cost ($) Subtotal	Cost ($) Total
EMBANKMENT					
Clearing and Grubbing	22	Acres	1,840.00	40,500	
Excavation	38,000	C.Y.	3.40	129,200	
Stream Diversion	1	L.S.	11,500.00	11,500	
Impervious Fill	279,000	C.Y.	2.30	641,700	
Riprap	10,200	C.Y.	34.50	351,900	
Bedding	6,120	C.Y.	16.10	98,500	
Filter Cloth	19,380	S.Y.	2.30	44,600	
Seeding	21,420	S.Y.	1.40	30,000	
SUBTOTAL				1,347,900	
CONTINGENCIES 20%				269,600	
TOTAL EMBANKMENT					1,617,500
RELIEF DRAINS					
Excavation	200	C.Y.	4.60	900	
Gravel Filter	200	C.Y.	16.10	3,200	
6" Perforated P.V.C.	300	C.Y.	5.80	1,700	
Concrete Ditch	50	C.Y.	1.70	8,500	
SUBTOTAL				14,300	
CONTINGENCIES 20%				2,900	
TOTAL RELIEF DRAINS					17,200
EMERGENCY SPILLWAY					
Clearing and Grubbing	10	Acres	1,840.00	18,400	
Excavation	134,000	C.Y.	2.90	388,600	
Concrete Liner	3,700	C.Y.	161.00	595,700	
Temp. Haul Road	1	L.S.	58,000.00	58,000	
SUBTOTAL				1,060,700	
CONTINGENCIES 20%				212,100	
TOTAL EMERGENCY SPILLWAY					1,272,800
RESERVOIR CLEARING					
Clearing	420	Acres	300.00	126,000	
SUBTOTAL				126,000	
CONTINGENCIES				25,200	
TOTAL RESERVOIR CLEARING					151,200
PIPELINE					
Clearing	13	Acres	1,840.00	23,900	
Excavation	345,000	C.Y.	1.70	586,500	
Backfill	265,000	C.Y.	1.20	318,000	
Pavement Patching	11,300	S.F.	9.20	104,000	
Steel Water Pipe	34,000	L.F	212.80	7,235,200	
Manholes	32	Ea.	460.00	14,700	
Concrete Spillway	1	L.S.	5,800.00	5,800	
Pump Station	1	L.S.	11,000,000.00	11,000,000	
Seeding	20	Acres	500.00	10,000	
SUBTOTAL				19,298,100	
CONTINGENCIES 20%				3,859,600	

TOTAL RELIEF DRAINS

EMERGENCY SPILLWAY					
Clearing and Grubbing	10	Acres	1,840.00	18,400	
Excavation	134,000	C.Y.	2.90	388,600	
Concrete Liner	3,700	C.Y.	161.00	595,700	
Temp. Haul Road	1	L.S.	58,000.00	58,000	
SUBTOTAL				1,060,700	
CONTINGENCIES 20%				212,100	
TOTAL EMERGENCY SPILLWAY					1,272,800
RESERVOIR CLEARING					
Clearing	420	Acres	300.00	126,000	
SUBTOTAL				126,000	
CONTINGENCIES				25,200	
TOTAL RESERVOIR CLEARING					151,200
PIPELINE					
Clearing	13	Acres	1,840.00	23,900	
Excavation	345,000	C.Y.	1.70	586,500	
Backfill	265,000	C.Y.	1.20	318,000	
Pavement Patching	11,300	S.F.	9.20	104,000	
Steel Water Pipe	34,000	L.F	212.80	7,235,200	
Manholes	32	Ea.	460.00	14,700	
Concrete Spillway	1	L.S.	5,800.00	5,800	
Pump Station	1	L.S.	11,000,000.00	11,000,000	
Seeding	20	Acres	500.00	10,000	
SUBTOTAL				19,298,100	
CONTINGENCIES 20%				3,859,600	
TOTAL PIPELINE					23,157,700
LAND AND EASEMENTS					
Acquisition	440	Acres	3,000.00	1,320,000	
Relocations - Homes	25	Ea.	40,000.00	1,000,000	
SUBTOTAL				2,320,000	
CONTINGENCIES 20%				464,000	
TOTAL-LAND AND EASEMENTS					2,784,000
ENGINEERING AND DESIGN @ 12%					3,480,000
SUPERVISION AND ADMINISTRATION @ 8%					2,320,000
TOTAL COST					34,800,500
TOTAL COST ROUNDED					34,800,000

B

Table C-13. DETAILED COST ESTIMATE FOR ALTERNATIVE 13

Description	Estimated Quantity	Unit	Unit Cost	Cost ($) Subtotal	Cost ($) Total
DREDGING BAILEY BAY					
Excavation (Mud Cat)	1,800,000	C.Y.	1.95	3,510,000	
Silt Screens	18,800	L.F.	11.50	216,200	
Mobilization and Demobilization	1	Job	L.S.	430,000	
SUBTOTAL				4,156,200	
CONTINGENCIES 20%				831,200	
TOTAL DREDGING COST					4,987,400
LAND AND EASEMENTS	884	Acres	400.00	353,600	
SUBTOTAL				353,600	
CONTINGENCIES 20%				70,700	
TOTAL LAND AND EASEMENTS COST					424,300
ENGINEERING AND DESIGN @ 12%					649,400
SUPERVISION AND ADMINISTRATION @ 8%					432,900
TOTAL COST					6,494,000
TOTAL COST ROUNDED					6,494,000

Table C-14. DETAILED COST ESTIMATE FOR ALTERNATIVE 13A

Description	Estimated Quantity	Unit	Unit Cost	Cost ($) Subtotal	Cost ($) Total
DREDGING BAILEY BAY					
Mud Cat Pay Yardage	1,321,000	C.Y.	1.95	2,576,000	
Silt Screens	14,100	L.F.	11.50	162,200	
Mobilization and Demobilization	1	Job	L.S.	240,000	
SUBTOTAL				2,978,200	
CONTINGENCIES 20%				595,600	
TOTAL DREDGING COST					3,573,800
LAND AND EASEMENTS	650	Acres	400.00	260,000	
SUBTOTAL				260,000	
CONTINGENCIES 20%				52,000	
TOTAL DREDGING COST					312,000
ENGINEERING AND DESIGN @ 12%					466,300
SUPERVISION AND ADMINISTRATION @ 8%					310,900
TOTAL COST					4,663,000
TOTAL COST ROUNDED					4,663,000

Table C-15. DETAILED COST ESTIMATE FOR ALTERNATIVE 14

Description	Estimated Quantity	Unit	Unit Cost	Cost ($) Subtotal	Cost ($) Total
LEVEE					
Stage 1 Hydraulic Fill	412,722	C.Y.	2.10	866,700	
Stage 2 Hydraulic Fill	367,333	C.Y.	2.10	771,400	
Reworded Hydraulic Fill	63,333	C.Y.	2.30	145,700	
Bentonite/Sand Slurry	42,750	C.Y.	11.50	491,600	
Riprap 200" Stone	32,722	C.Y.	34.50	1,128,900	
Gravel Bedding	16,361	C.Y.	13.80	255,800	
Filter Cloth	285,000	S.F.	1.70	484,500	
Crushed Gravel	12,139	C.Y.	16.10	195,400	
SUBTOTAL				4,340,000	
CONTINGENCIES 20%				868,000	
TOTAL LEVEE COST					5,208,000
EMERGENCY SPILLWAY	1	Job	L.S.	3,500	
SUBTOTAL				3,500	
CONTINGENCIES 20%				700	
TOTAL EMERGENCY SPILLWAY COST					4,200
LAND AND EASEMENTS	884	Acres	400.00	353,600	
SUBTOTAL				353,600	
CONTINGENCIES 20%				70,700	
TOTAL LAND AND EASEMENTS COSTS					424,300
ENGINEERING AND DESIGN @ 12%					676,400
SUPERVISION AND ADMINISTRATION @ 8%					450,900
TOTAL COST					6,763,800
TOTAL COST ROUNDED					6,764,000

Table C-16. DETAILED COST ESTIMATE FOR ALTERNATIVE 15

Description	Estimated Quantity	Unit	Unit Cost	Cost ($) Subtotal	Cost ($) Total
GRAVELLY RUN DIVERSION DAM AND PRESSURE CONDUIT	(SEE TABLE C-3, Alternative 2A)			8,111,000	
DAM AT MOUTH OF BAILEY CREEK 26.5' m.s.l.	(SEE TABLE C-8, Alternative 7E)			12,326,000	
DREDGING ALL OF BAILEY BAY AND DISPOSING IN BAILEY CREEK	(SEE TABLE C-13, Alternative 13)			6,494,000	
TOTAL COST					26,931,000

Table C-17. DETAILED COST ESTIMATE FOR ALTERNATIVE 17

Description	Estimated Quantity	Unit	Unit Cost	Cost ($) Subtotal	Cost ($) Total
DREDGING GRAVELLY RUN	(SEE TABLE C-5, Alternative 6)				855,100
DREDGING BAILEY CREEK	(SEE TABLE C-10, Alternative 11)				13,342,000
DREDGING BAILEY BAY					
Mud Cat Pay Yardage	1,321,000	C.Y.	1.95	2,576,000	
Silt Screens	14,100	Ft.	11.90	162,200	
Mobilization and Demobilization	1	Job	L.S.	240,000	
Land and Easements	650	Acres	400.00	260,000	
SUBTOTAL				3,238,200	
CONTINGENCIES 20%				647,600	
TOTAL DREDGING BAILEY BAY COST					3,885,800
DISPOSAL SITE	(SEE TABLE C-18)				5,715,900
ENGINEERING AND DESIGN @ 12%					2,855,900
SUPERVISION AND ADMINISTRATION @ 8%					1,903,900
TOTAL COST					28,558,600
TOTAL COST ROUNDED					28,559,000

Table C-18. DETAILED COST ESTIMATE FOR BAILEY BAY DISPOSAL AREA

Description	Estimated Quantity	Unit	Unit Cost	Cost ($) Subtotal	Cost ($) Total
LEVEE					
Stage 1 Hydraulic Fill	254,874	C.Y.	2.10	535,200	
Stage 2 Hydraulic Fill	226,844	C.Y.	2.10	476,400	
Reworked Hydraulic Fill	39,111	C.Y.	2.30	90,000	
Bentonite/Sand Slurry	26,400	C.Y.	11.50	303,600	
Riprap 200# Stone	20,207	C.Y.	34.50	697,100	
Gravel Bedding	10,104	C.Y.	13.80	139,400	
Filter Cloth	176,000	S.F.	1.70	299,200	
Crushed Gravel	7,496	C.Y.	16.10	120,700	
SUBTOTAL				2,661,600	
CONTINGENCIES 20%				532,300	
TOTAL LEVEE COST					3,193,900
EMERGENCY SPILLWAY	1	Job	L.S.	3,500	
SUBTOTAL				3,500	
CONTINGENCIES 20%				700	
TOTAL EMERGENCY SPILLWAY COST					4,200
CLAY SEAL					
1' Clay Layer	377,520	C.Y.	2.00	755,000	
6" Top Soil	188,760	C.Y.	6.00	1,132,600	
Seeding	234	Acres	500.00	117,000	
SUBTOTAL				2,004,600	
CONTINGENCIES 20%				400,900	
TOTAL CLAY SEAL COST					2,405,500
LAND AND EASEMENTS	234	Acres	400.00	93,600	
SUBTOTAL				93,600	
CONTINGENCIES 20%				18,700	
TOTAL LAND AND EASEMENTS COST					112,300
ENGINEERING AND DESIGN @ 12%					685,900
SUPERVISION AND ADMINISTRATION @ 8%					457,300
TOTAL COST					6,859,100
TOTAL COST ROUNDED					6,859,000

SECTION D

SURVEYS

SECTION D

SURVEYS

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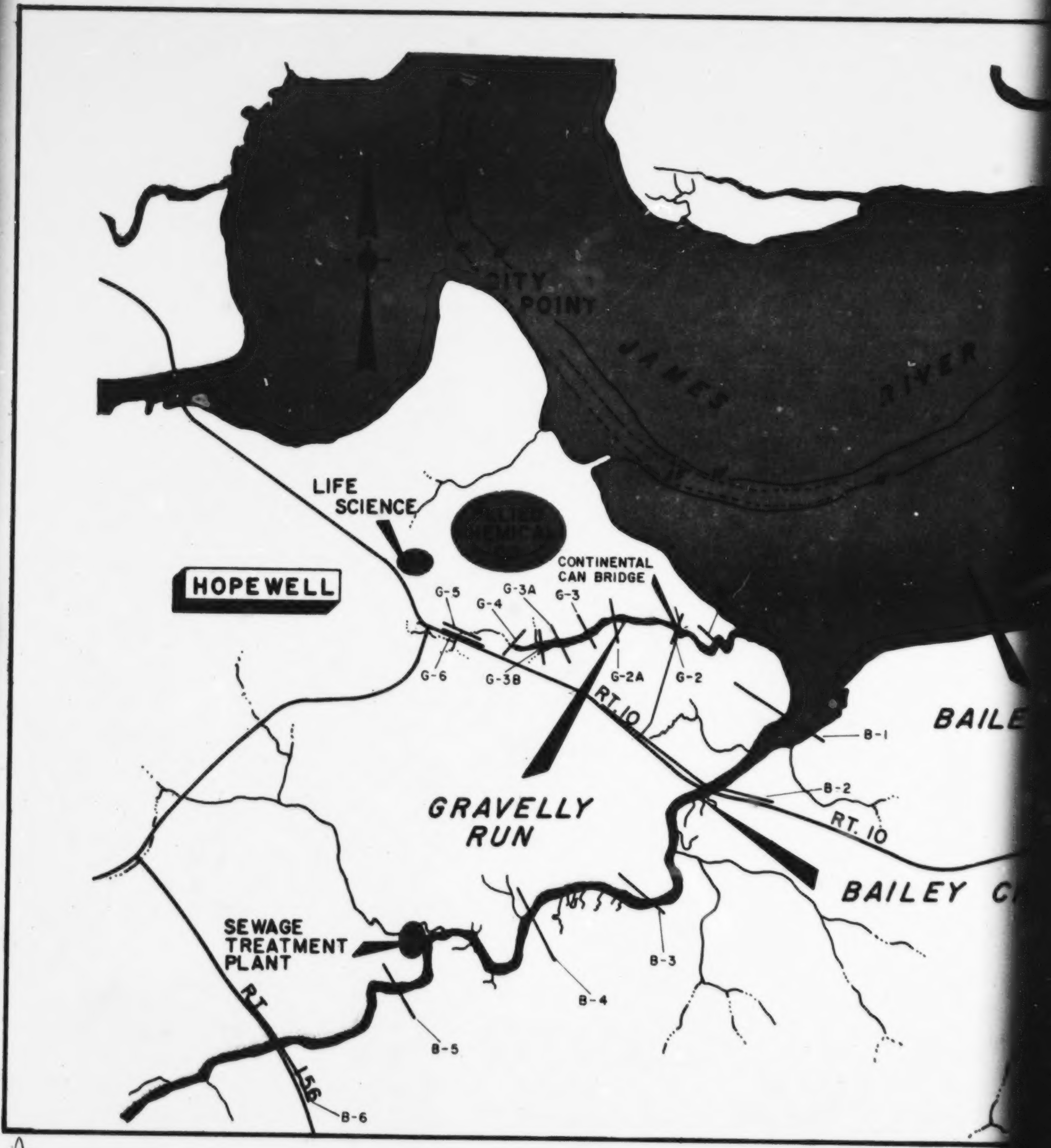
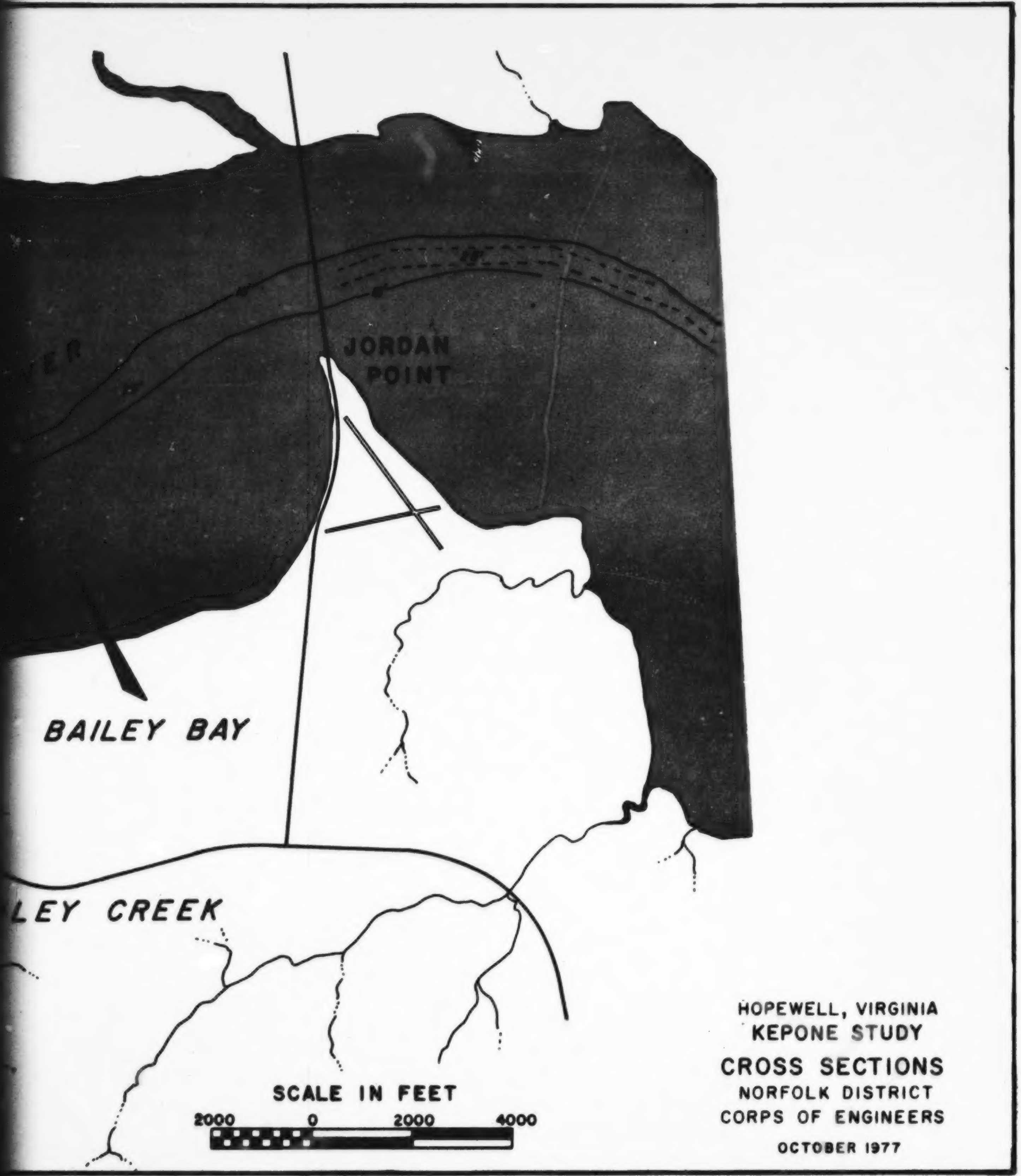
INTRODUCTION

As stated in the main report, cross-sections were obtained to aid in the development of preliminary design and cost estimates. Cross-sections were obtained in both Bailey Creek and Gravelly Run. In all, 15 cross-sections were obtained. The location of each section is shown on plate D-1 with the individual cross-sections shown on plates D-2 through D-16.


CITY POINT
JAMES RIVER
LIFE SCIENCE
ALLIED CHEMICAL
HOPEWELL
CONTINENTAL CAN BRIDGE
G-5
G-4
G-3A
G-3
G-6
G-3B
G-2A
G-2
RT. 10
B-1
BAILE
GRAVELLY RUN
B-2
RT. 10
BAILEY C
SEWAGE TREATMENT PLANT
B-3
B-4
B-5
RT. 156
B-6

A

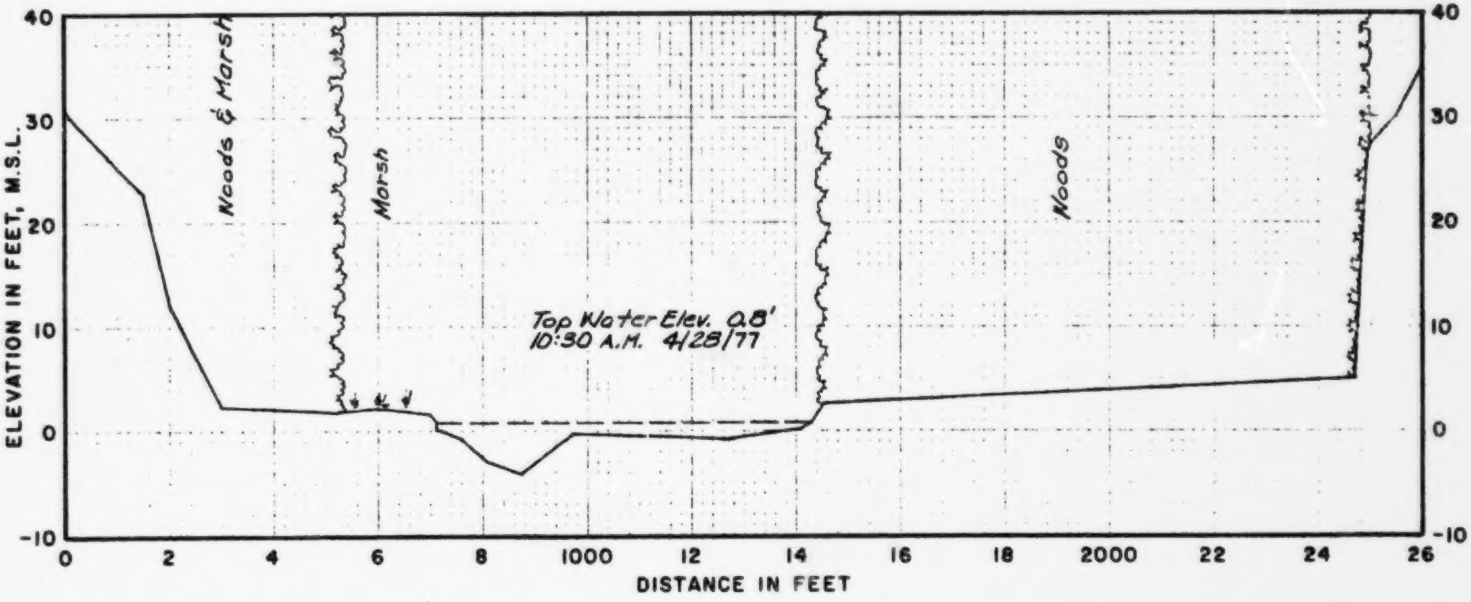
1


VER
JORDAN POINT
BAILEY BAY
LEY CREEK
SCALE IN FEET
2000 0 2000 4000

HOPEWELL, VIRGINIA
KEPONE STUDY
CROSS SECTIONS
NORFOLK DISTRICT
CORPS OF ENGINEERS
OCTOBER 1977

B

PLATE D-1



HOPEWELL, VIRGINIA
KEPONE STUDY
CROSS SECTION B-1
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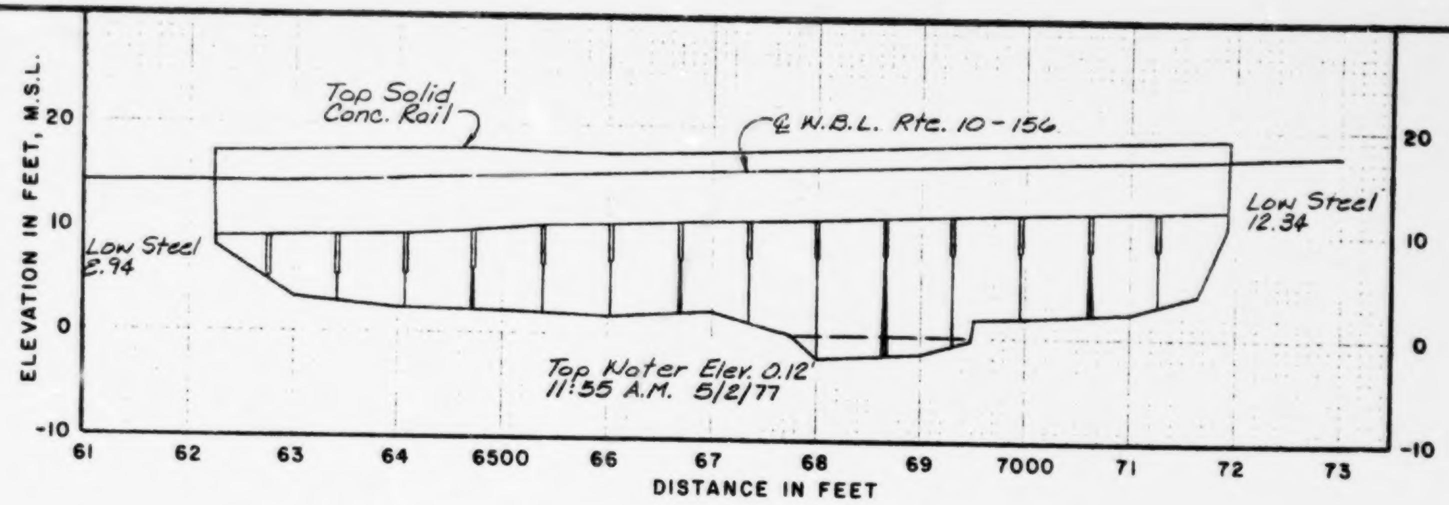
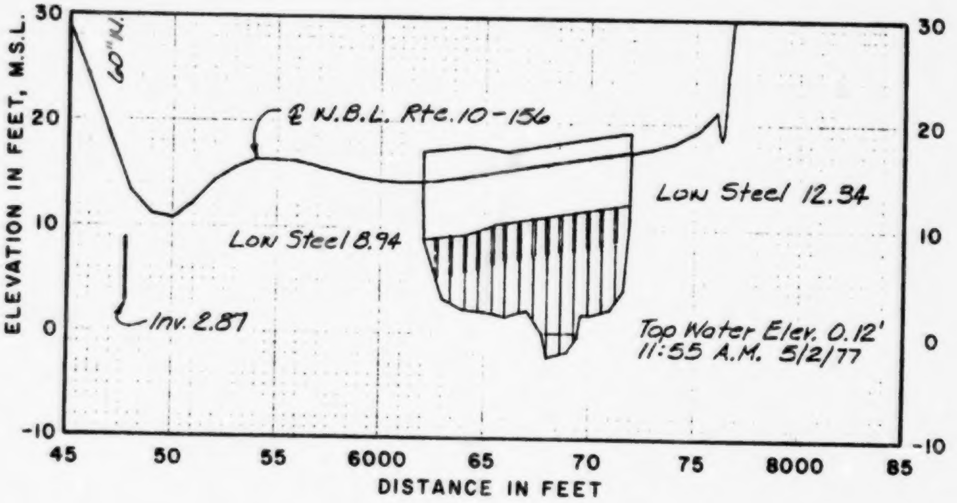




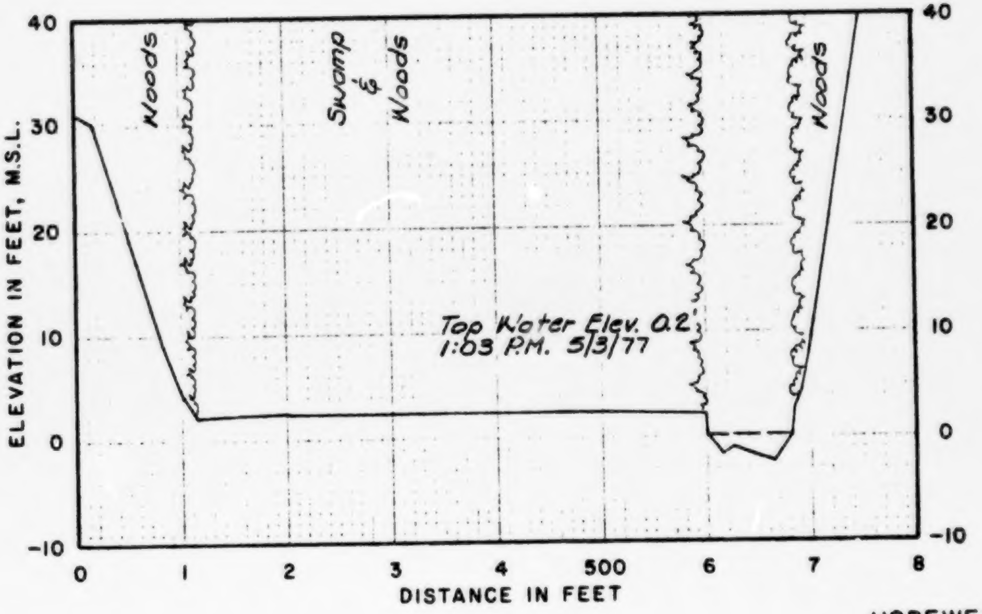
HOPEWELL, VIRGINIA

KEPONE STUDY

CROSS SECTION B-2

NORFOLK DISTRICT
CORPS OF ENGINEERS

OCTOBER 1977



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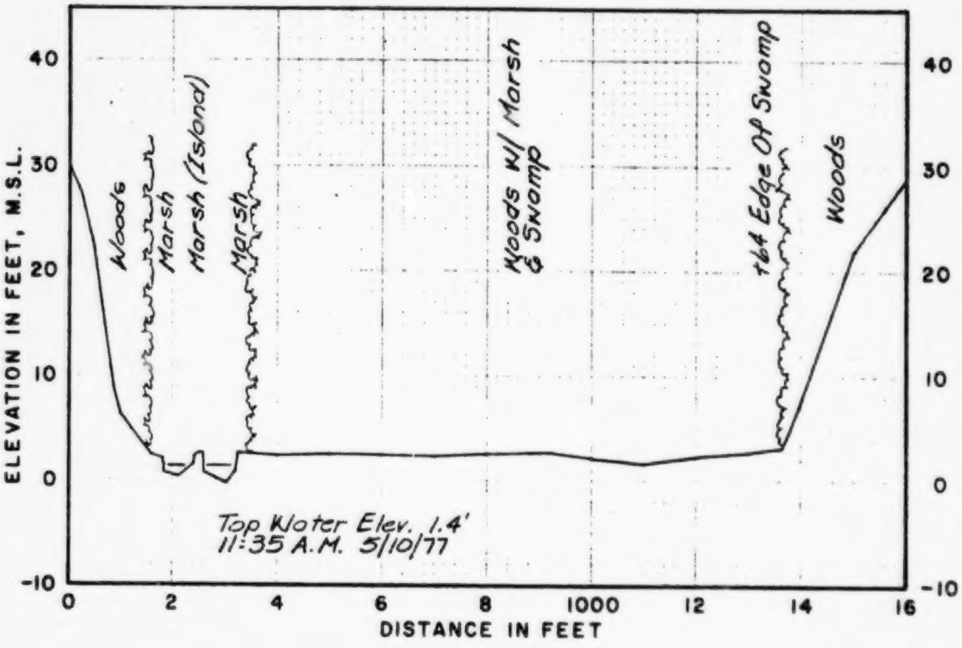
KEPONE STUDY
CROSS SECTION B-3
NORFOLK DISTRICT
CORPS OF ENGINEERS
OCTOBER 1977



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NORFOLK DISTRICT
CORPS OF ENGINEERS
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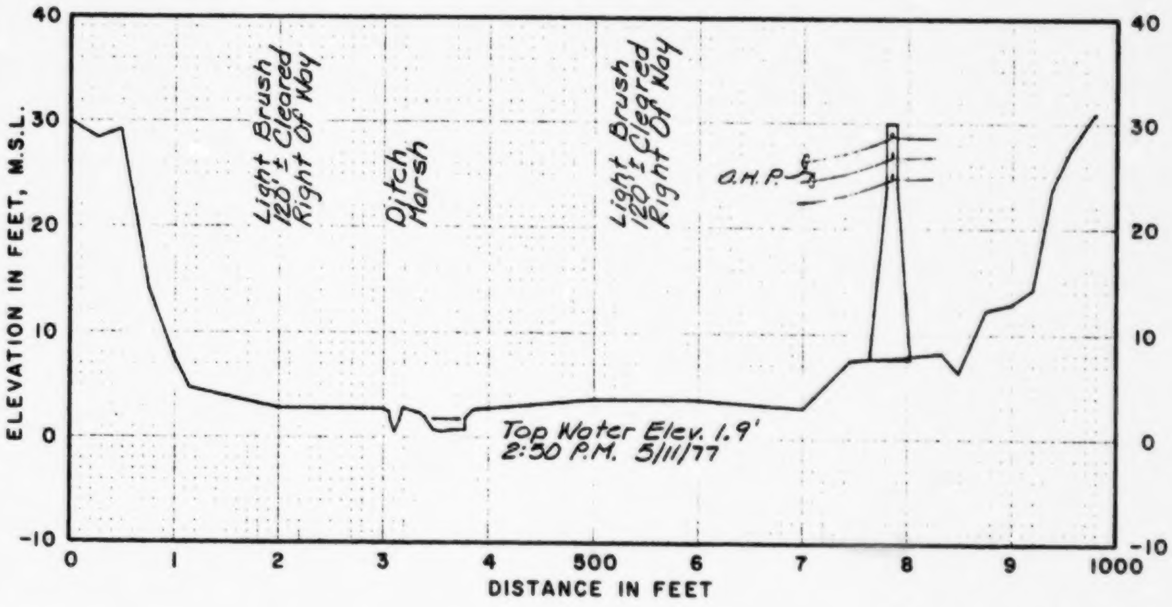
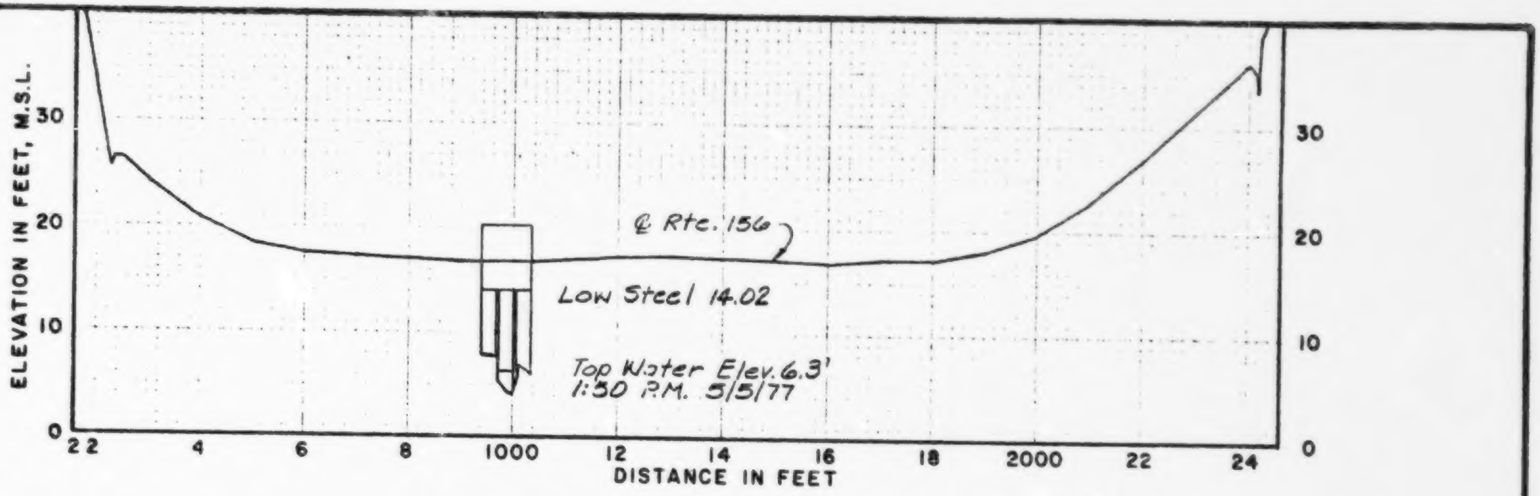
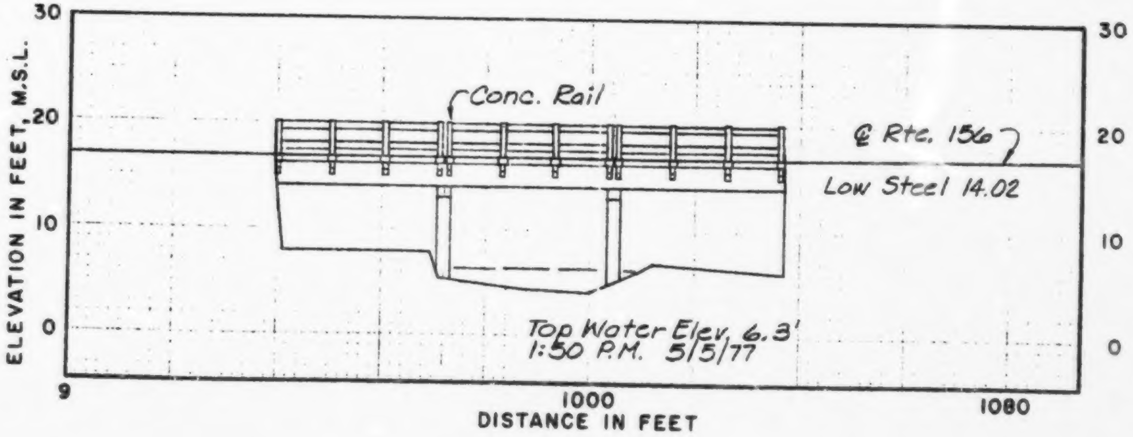
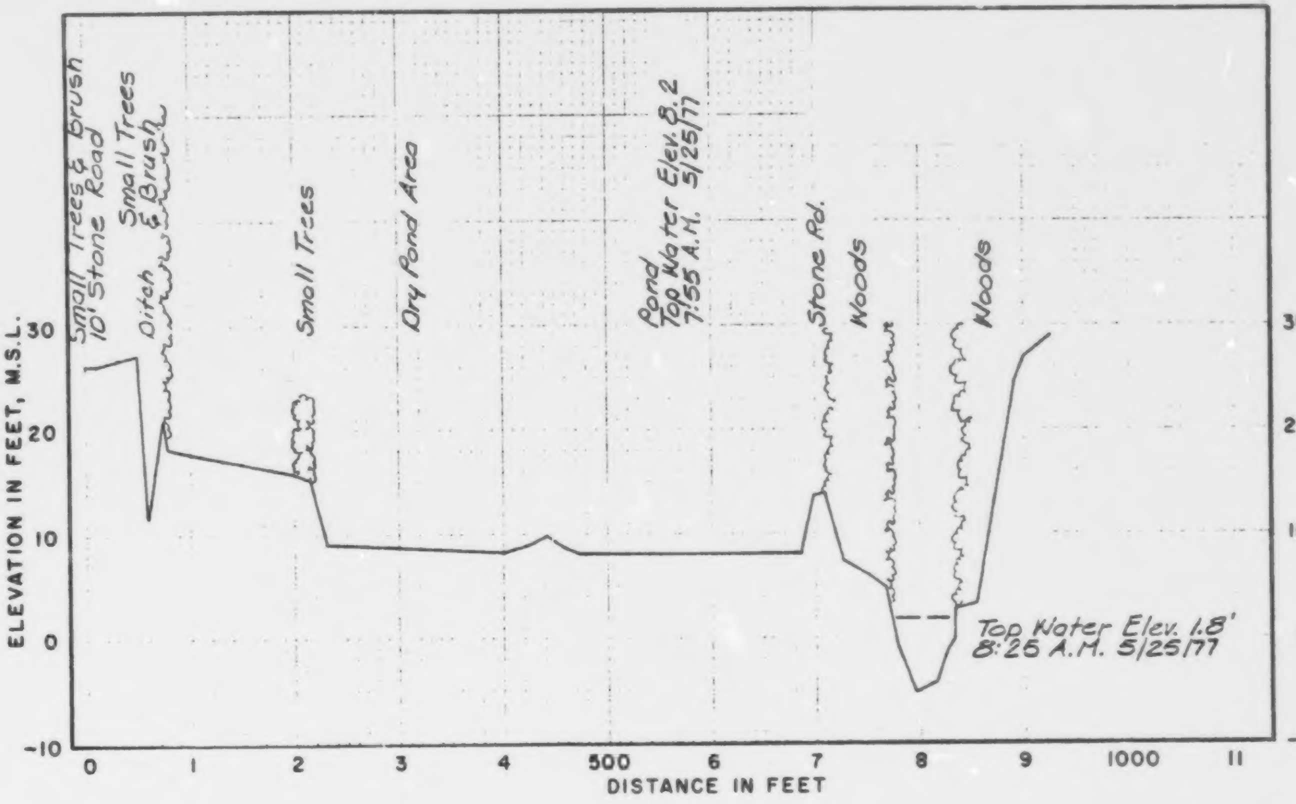


HOPEWELL, VIRGINIA
KEPONE STUDY
CROSS SECTION B-5
NORFOLK DISTRICT
CORPS OF ENGINEERS
OCTOBER 1977

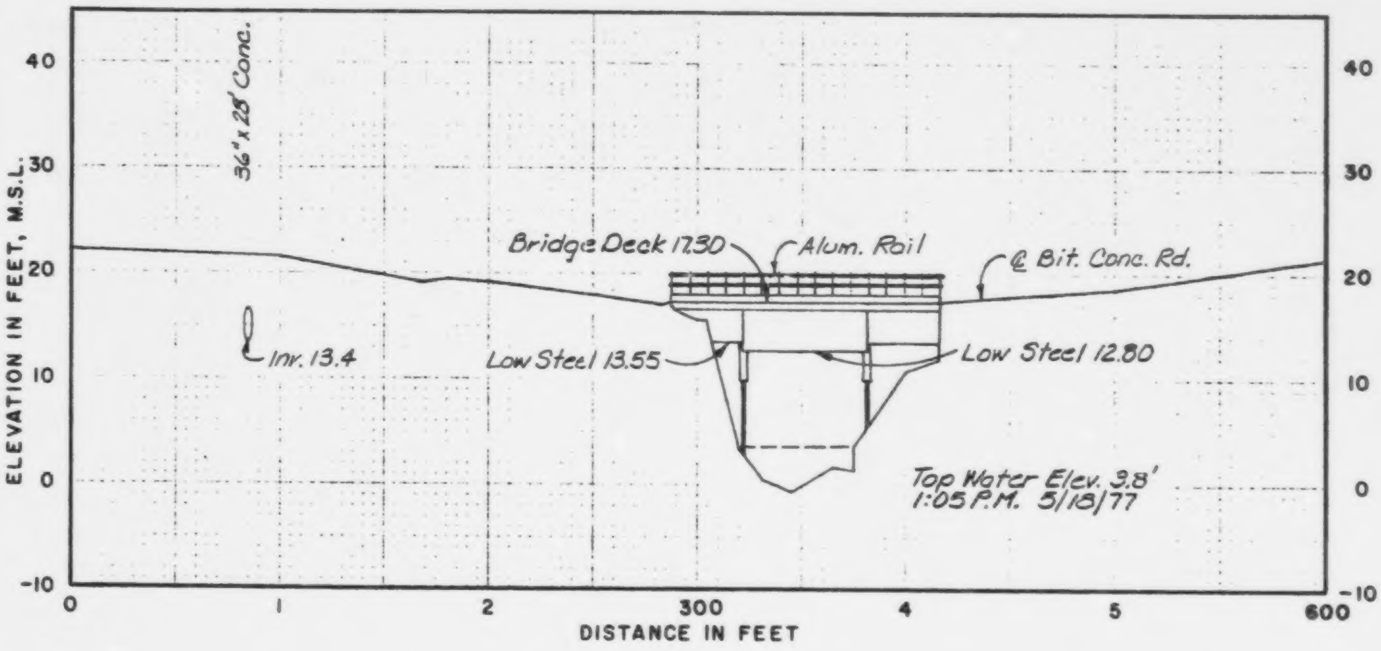



ELEVATION IN FEET, M.S.L.
30
20
10
0
9
1000
1080
DISTANCE IN FEET
Conc. Rail
℄ Rte. 156
Low Steel 14.02
Top Water Elev. 6.3'
1:50 P.M. 5/5/77

HOPEWELL, VIRGINIA
KEPONE STUDY
CROSS SECTION B-6
NORFOLK DISTRICT
CORPS OF ENGINEERS
OCTOBER 1977



HOPEWELL, VIRGINIA
KEPONE STUDY
CROSS SECTION G-1
NORFOLK DISTRICT
CORPS OF ENGINEERS
OCTOBER 1977



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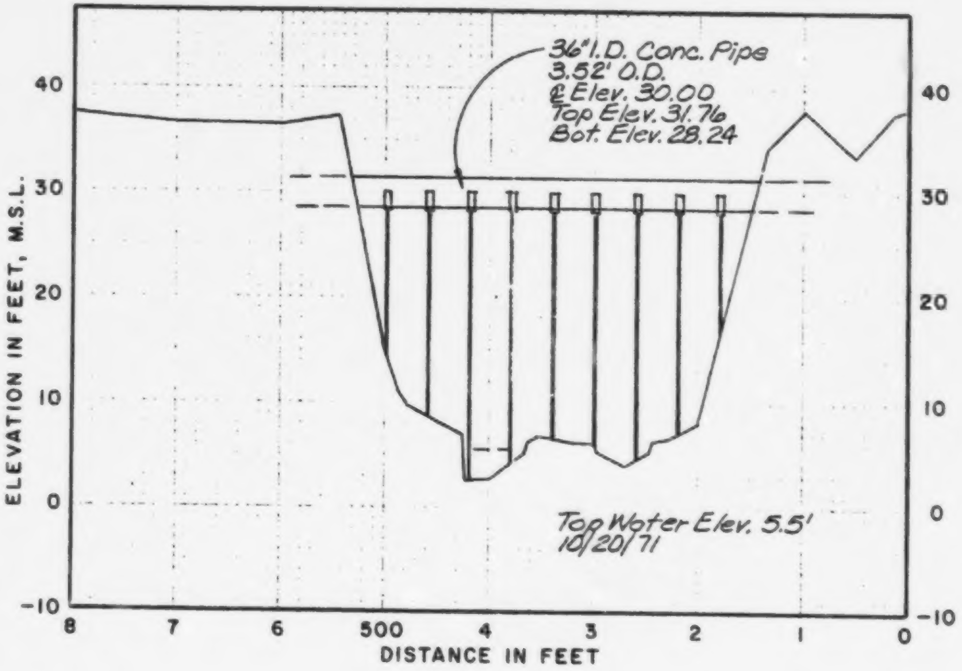
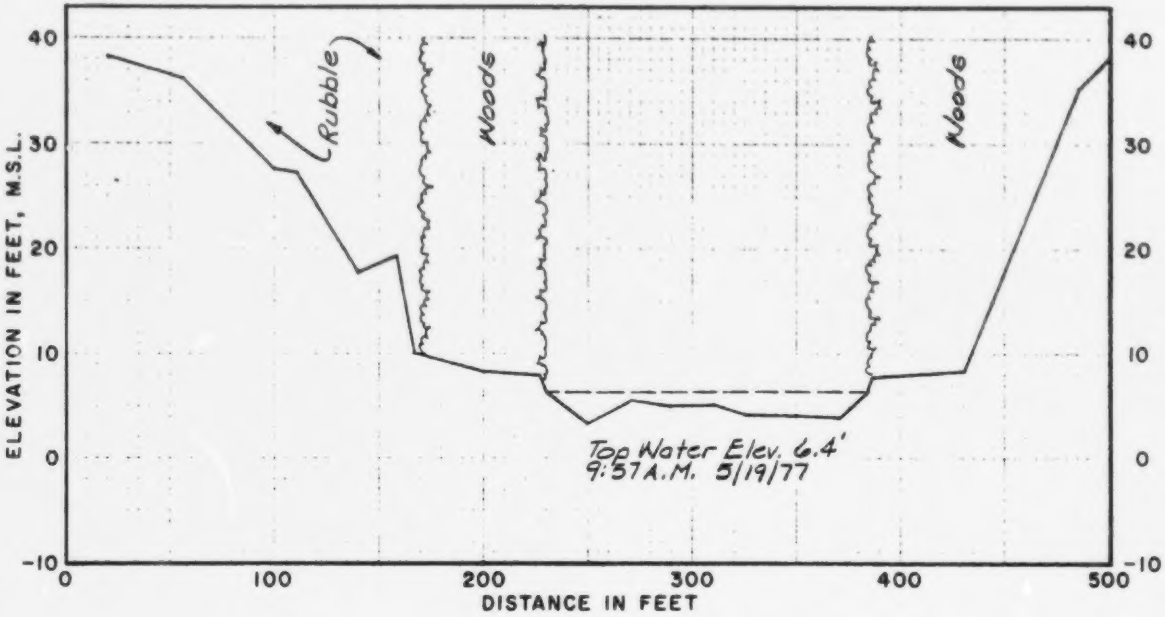


HOPEWELL, VIRGINIA
KEPONE STUDY
CROSS SECTION G-2A
NORFOLK DISTRICT
CORPS OF ENGINEERS
OCTOBER 1977



HOPEWELL, VIRGINIA
KEPONE STUDY
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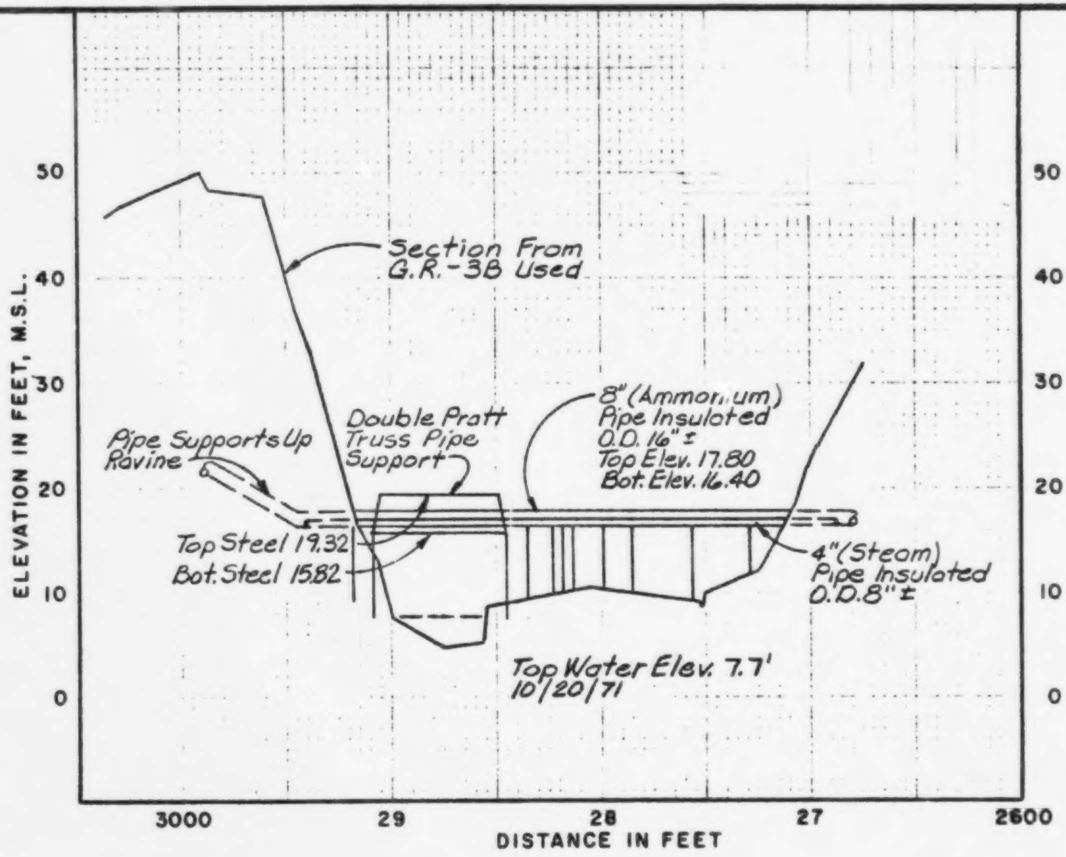
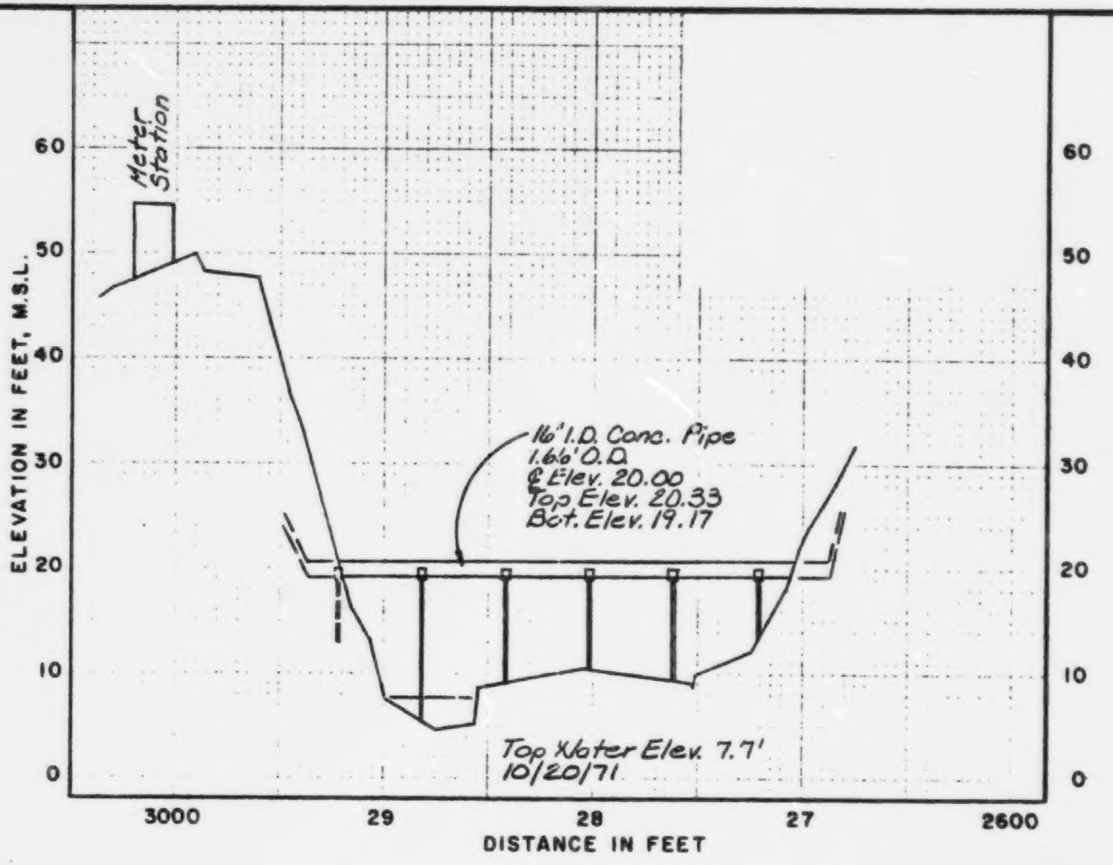
NORFOLK DISTRICT
CORPS OF ENGINEERS
OCTOBER 1977


ELEVATION IN FEET, M.S.L.
50
40
30
20
10
0
Section From G.R.-3B Used
Pipe Supports Up Ravine
Double Pratt Truss Pipe Support
8" (Ammonium) Pipe Insulated O.D. 16" ±
Top Elev. 17.80
Bot. Elev. 16.40
Top Steel 19.32
Bot. Steel 15.82
4" (Steam) Pipe Insulated O.D. 8" ±
Top Water Elev. 7.7'
10/20/71
3000
29
28
27
2600
DISTANCE IN FEET

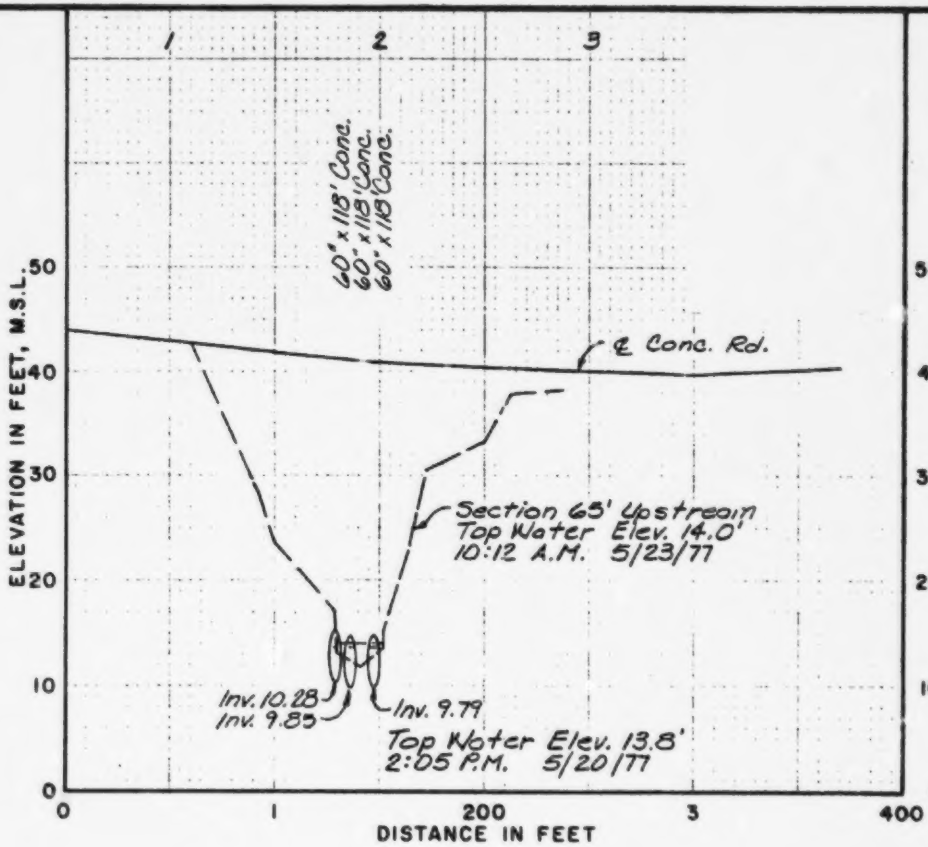
HOPEWELL, VIRGINIA
KEPONE STUDY
CROSS SECTION G-3A
NORFOLK DISTRICT
CORPS OF ENGINEERS
OCTOBER 1977

PLATE D-12


Meter Station
ELEVATION IN FEET, M.S.L.
60
50
40
30
20
10
0
16' I.D. Conc. Pipe
1.66' O.D.
℄ Elev. 20.00
Top Elev. 20.33
Bot. Elev. 19.17
Top Water Elev. 7.7'
10/20/71
3000
29
28
27
2600
DISTANCE IN FEET

HOPEWELL, VIRGINIA
KEPONE STUDY
CROSS SECTION G-3B
NORFOLK DISTRICT
CORPS OF ENGINEERS

OCTOBER 1977



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KEPONE STUDY
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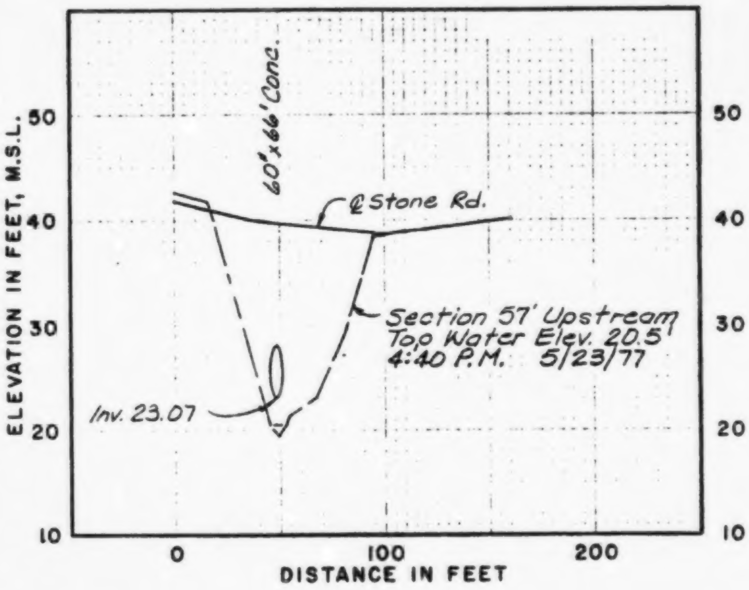
NORFOLK DISTRICT
CORPS OF ENGINEERS
OCTOBER 1977

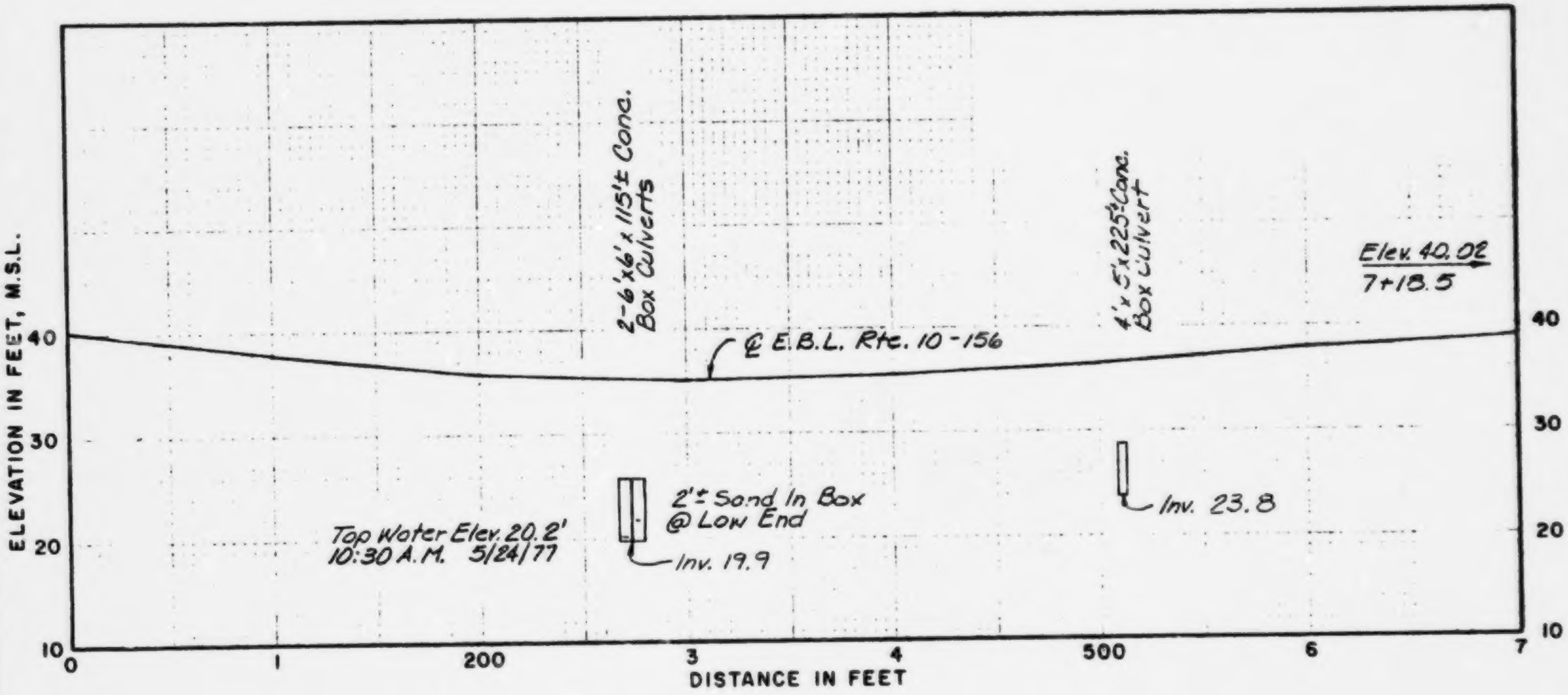


HOPEWELL, VIRGINIA
KEPONE STUDY

CROSS SECTION G-5

NORFOLK DISTRICT
CORPS OF ENGINEERS

OCTOBER 1977



HOPEWELL, VIRGINIA
KEPONE STUDY
CROSS SECTION G-6
NORFOLK DISTRICT
CORPS OF ENGINEERS
OCTOBER 1977

SECTION E

SUBSURFACE INVESTIGATIONS

SECTION E

SUBSURFACE INVESTIGATIONS

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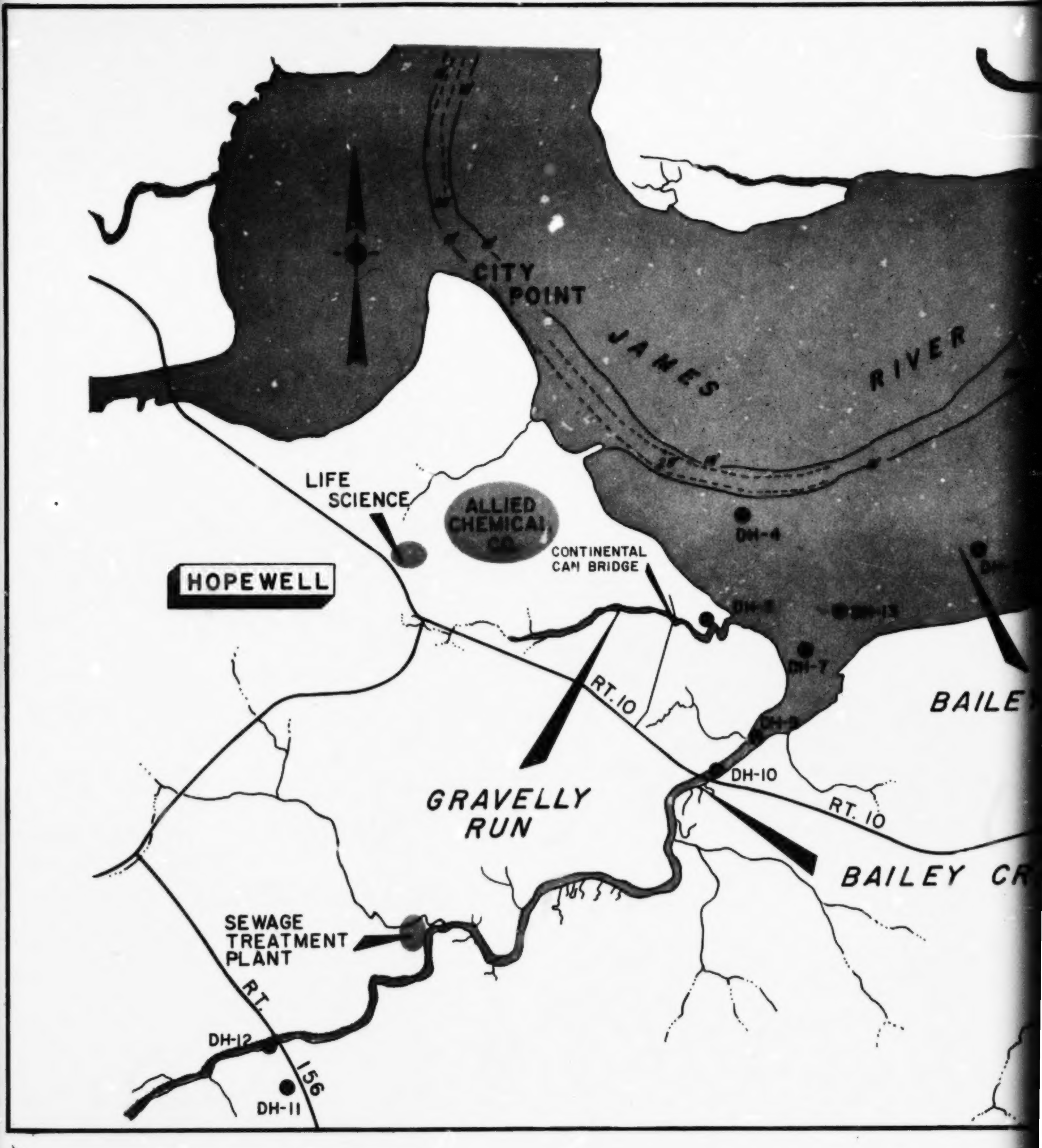
E-5	DRILL HOLES 8 AND 9
E-6	DRILL HOLES 10 AND 11
E-7	DRILL HOLE 12
E-8	DRILL HOLE 13

INTRODUCTION

A limited amount of subsurface investigations were accomplished during this phase of the Kepone study. The scope of the investigation and the results are discussed in the main report. The locations of the borings obtained are shown on plate E-1 with the individual boring logs shown on plates E-2 through E-8.


CITY POINT
JAMES RIVER
LIFE SCIENCE
ALLIED CHEMICAL CO.
CONTINENTAL CAN BRIDGE
HOPEWELL
DH-4
DH-8
DH-13
DH-7
DH-9
DH-10
RT. 10
RT. 10
BAILE
GRAVELLY RUN
BAILEY CR
SEWAGE TREATMENT PLANT
RT. 156
DH-12
DH-11

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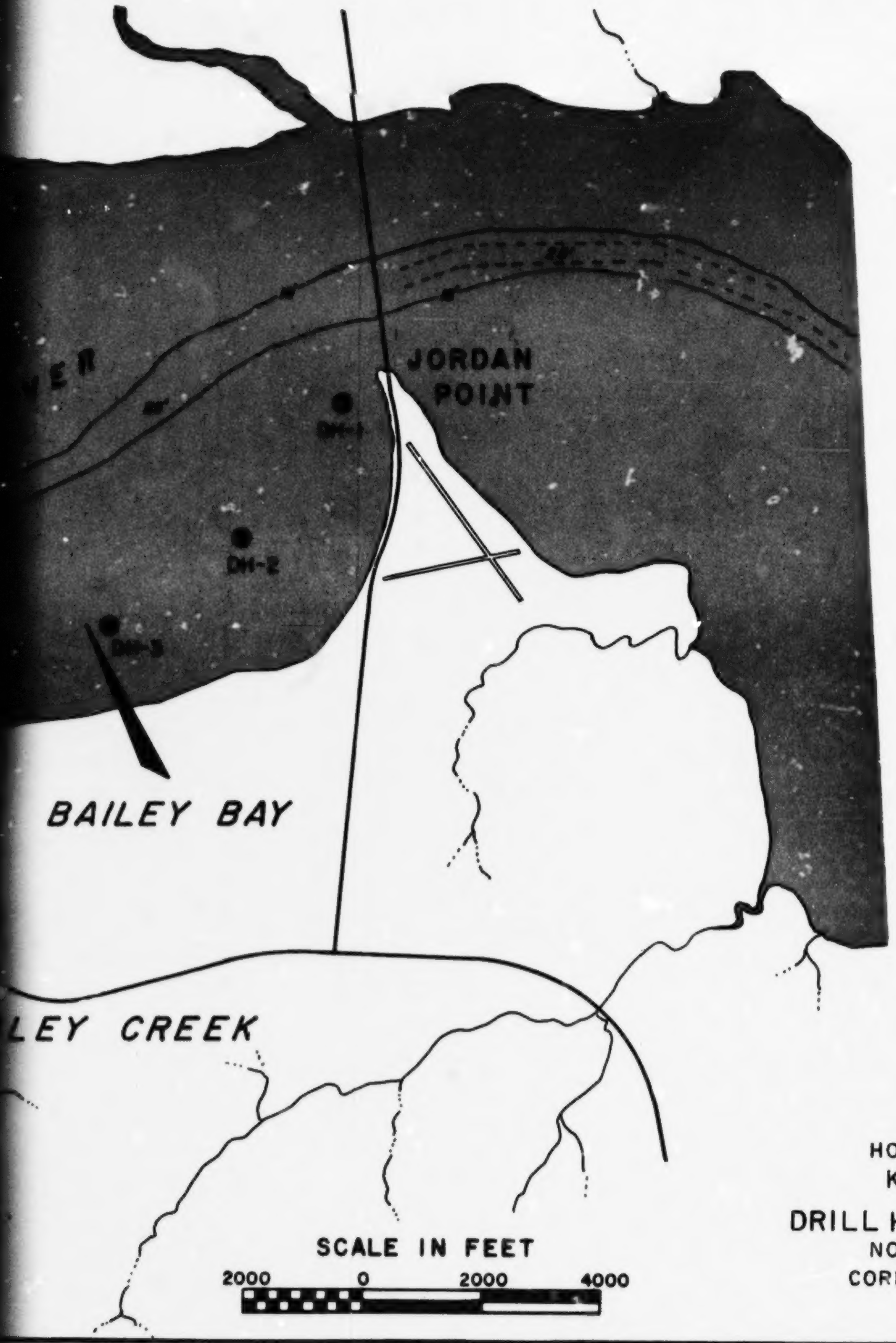
VER
JORDAN POINT
DH-1
DH-2
DH-3
BAILEY BAY
LEY CREEK
SCALE IN FEET
2000
0
2000
4000

HOPEWELL, VIRGINIA
KEPONE STUDY

DRILL HOLE LOCATIONS

NORFOLK DISTRICT
CORPS OF ENGINEERS

OCTOBER 1977

B

454<

PLATE E-1

Hole No. DH-1

DRILLING LOG	DIVISION NAD	INSTALLATION NAO	SHEET 1 OF 1 SHEETS

1. PROJECT: KEPONE STUDY, HOPEWELL, VA.
2. LOCATION (Coordinates or Station): BAILEYS BAY N 3585734 E 2371202.1
3. DRILLING AGENCY: CUNNINGHAM DRILLING & GROUTING
4. HOLE NO. (As shown on drawing title and file number): DH-1
5. NAME OF DRILLER: W. BALLARD
6. DIRECTION OF HOLE: ☑ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: 31.0'
8. DEPTH DRILLED INTO ROCK: 0.0'
9. TOTAL DEPTH OF HOLE: 31.0'
10. SIZE AND TYPE OF BIT: 2" OD SPLIT SPOON
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: SEH-40C
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 7 UNDISTURBED 0
14. TOTAL NUMBER CORE BOXES: 0
15. ELEVATION GROUND WATER:
16. DATE HOLE: STARTED 11 MAY 77 COMPLETED 11 MAY 77
17. ELEVATION TOP OF HOLE: BTM ELEV -3.9'
18. TOTAL CORE RECOVERY FOR BORING: — %
19. SIGNATURE OF INSPECTOR: R Buck

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g		
-3.9			(SP-SM) fn. micaceous SAND, tr. org. silt, dk. gr.		S-1	SPLIT SPOON	2-1/12"	0 1.5
						(93% SAND) WASHED W/CASING		
-6.4	2.5		(SP-GP) fn. to crse. SAND & GRAVEL, gray & yellow		S-2	SPLIT SPOON	?-19-12	4.5 6.0
-11.4	7.5		(SP) fn. to med SAND (98%), gray & yellow			WASHED W/CASING		
					S-3	SPLIT SPOON	7-9-8	9.5 11.0
						WASHED W/CASING		
					S-4	SPLIT SPOON	4-7-9	14.5 16.0
						WASHED W/CASING		
-21.9	18.0		(SC) fn. SAND & clay med. plastic, gray		S-5	SPLIT SPOON	3-6-11	19.5 21.0
						WASHED W/CASING		
-26.4	22.5		(GC-SC) GRAVEL & fn. sand, little to some clay, olive		S-6	SPLIT SPOON	6-8-8	24.5 26.0
						WASHED W/CASING		
-31.4	27.5		(SC) fn. SAND some clay & silt, med. plast., dk. green gray		S-7	SPLIT SPOON	9-14-17	29.5 31.0
-33.9	31.0		BOTTOM HOLE					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT) PROJECT HOLE NO.

Hole No. DH-2

DRILLING LOG	DIVISION NAD	INSTALLATION NAO	SHEET OF 1 SHEETS

1. PROJECT: KEPONE STUDY, HOPEWELL, VA
2. LOCATION (Coordinates or Station): BAILEY'S BAY N 356084.4 E2369147.4
3. DRILLING AGENCY: CUNNINGHAM DRILLING & GROUTING
4. HOLE NO. (As shown on drawing title and file number): DH-2
5. NAME OF DRILLER: W. BALLARD
6. DIRECTION OF HOLE: ☑ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: 36.0'
8. DEPTH DRILLED INTO ROCK: 0.0'
9. TOTAL DEPTH OF HOLE: 36.0'
10. SIZE AND TYPE OF BIT: 2" OD SPLIT SPOON
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: SEH-40C
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 8 UNDISTURBED 0
14. TOTAL NUMBER CORE BOXES: 0
15. ELEVATION GROUND WATER:
16. DATE HOLE: STARTED 11 MAY 77 COMPLETED 11 MAY 77
17. ELEVATION TOP OF HOLE: BTM. ELEV -4.0'
18. TOTAL CORE RECOVERY FOR BORING: — %
19. SIGNATURE OF INSPECTOR: R Buck

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g		
-4.0			(OH) highly organic CLAY, some silt, black		S-1	SPLIT SPOON	W/H	0.0 1.5
						WASHED W/CASING		
					S-2	SPLIT SPOON	W/H	4.5 6.0
						WASHED W/CASING		
					S-3	SPLIT SPOON	W/H	9.5 11.0
-17.0	13.0		(SM) fn. mica. SAND and organic fines black			WASHED W/CASING		
					S-4	SPLIT SPOON	W/H	14.5 16.0
-22.0	18.0		(SM) fn. mica. SAND, some org. fines, dk. gray (68% sand)			WASHED W/CASING		
					S-5	SPLIT SPOON	W/H	19.5 21.0
-27.0	23.0		(SM) fn. mica. SAND little org. fines, dk. gray (85% sand)			WASHED W/CASING		
					S-6	SPLIT SPOON	2-5-8	24.5 26.0
-32.0	28.0		(SM) fn. mica SAND some org. fines, black (79% sand)			WASHED W/CASING		
					S-7	SPLIT SPOON	W/H	29.5 31.0
						WASHED W/CASING		
					S-8	SPLIT SPOON	1/18"	34.5 36.0
-40.0	36.0		BOTTOM HOLE					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT) PROJECT HOLE NO.

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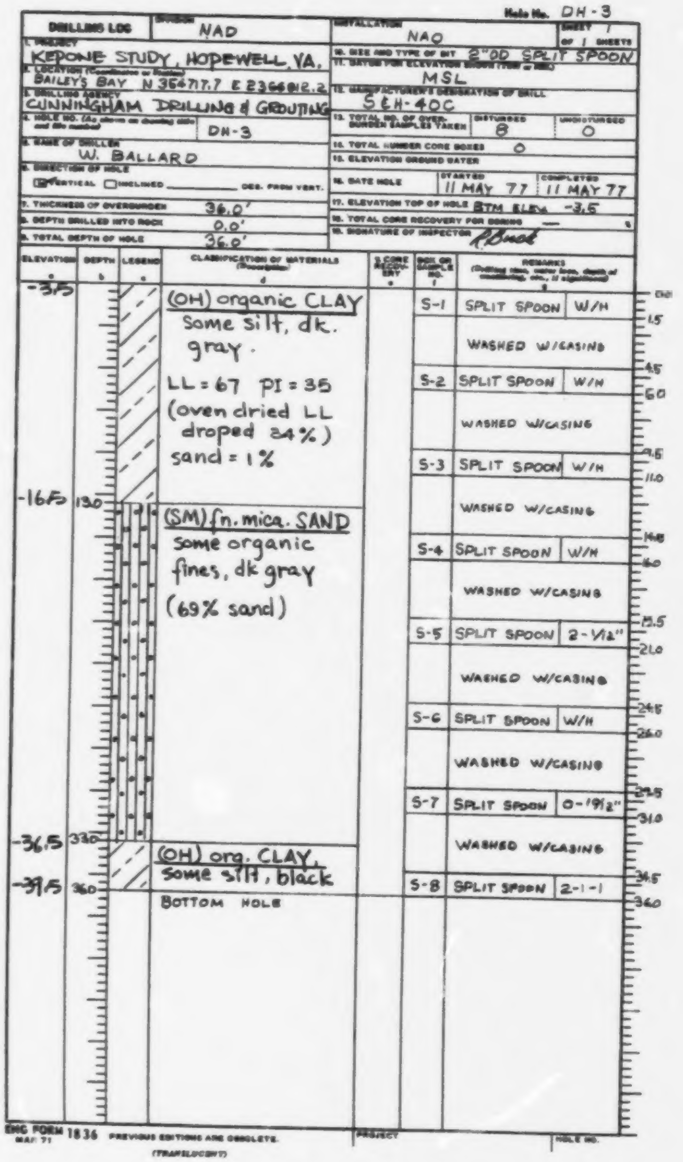
PLATE E-2



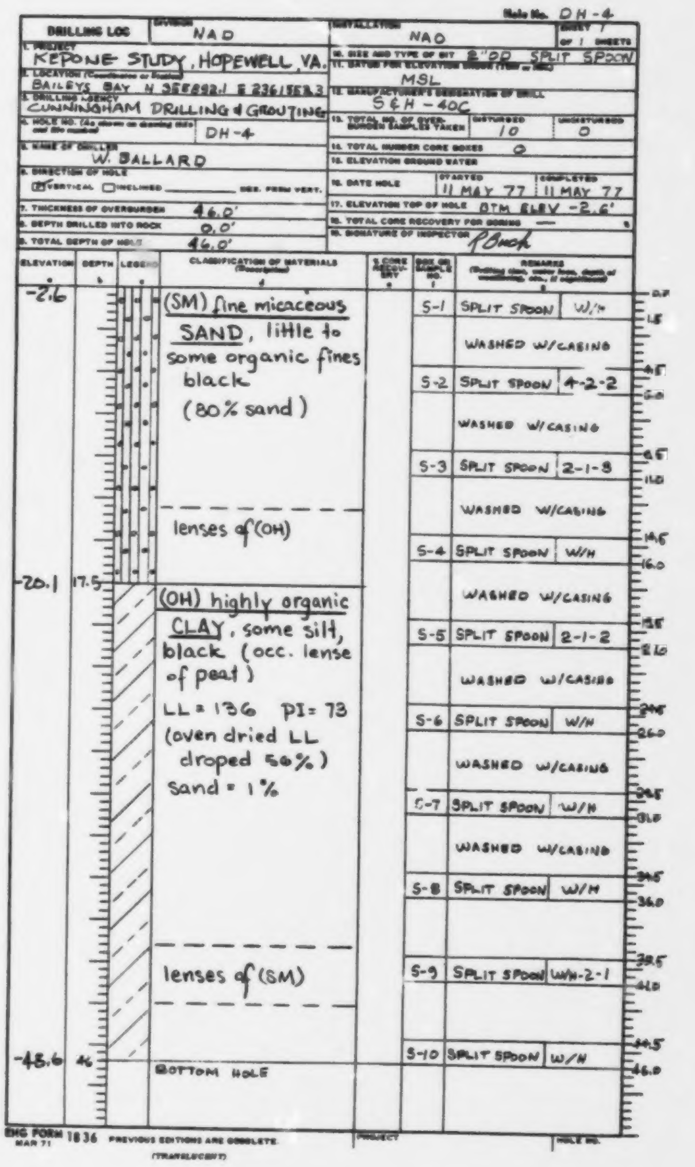
Hole No. DH-3

DRILLING LOG
DIVISION NAD
INSTALLATION NAQ
SHEET 1 OF 1 SHEETS
1. PROJECT KEPONE STUDY, HOPEWELL, VA.
2. LOCATION (Coordinates or Station) BAILEY'S BAY N 364717.7 E 2366812.2
3. DRILLING AGENCY CUNNINGHAM DRILLING & GROUTING
4. HOLE NO. (As shown on drawing title and file number) DH-3
5. NAME OF DRILLER W. BALLARD
6. DIRECTION OF HOLE ☑ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN 36.0'
8. DEPTH DRILLED INTO ROCK 0.0'
9. TOTAL DEPTH OF HOLE 36.0'
10. SIZE AND TYPE OF BIT 2"OD SPLIT SPOON
11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL
12. MANUFACTURER'S DESIGNATION OF DRILL S&H-40C
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN DISTURBED 8 UNDISTURBED 0
14. TOTAL NUMBER CORE BOXES 0
15. ELEVATION GROUND WATER
16. DATE HOLE STARTED 11 MAY 77 COMPLETED 11 MAY 77
17. ELEVATION TOP OF HOLE BTM ELEV -3.5
18. TOTAL CORE RECOVERY FOR BORING — %
19. SIGNATURE OF INSPECTOR R Buck

ELEVATION a	DEPTH b	CLASSIFICATION OF MATERIALS (Description) d
-3.5		(OH) organic CLAY some silt, dk. gray. LL = 67 PI = 35 (oven dried LL droped 24%) sand = 1%
-16.5	13.0	(SM) fn. mica. SAND some organic fines, dk gray (69% sand)
-36.5	33.0	(OH) org. CLAY, some silt, black
-39.5	36.0	BOTTOM HOLE

	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g	
0.0–1.5		S-1	SPLIT SPOON	W/H
			WASHED W/CASING	
4.5–6.0		S-2	SPLIT SPOON	W/H
			WASHED W/CASING	
9.5–11.0		S-3	SPLIT SPOON	W/H
			WASHED W/CASING	
14.5–16.0		S-4	SPLIT SPOON	W/H
			WASHED W/CASING	
19.5–21.0		S-5	SPLIT SPOON	2-1/12"
			WASHED W/CASING	
24.5–26.0		S-6	SPLIT SPOON	W/H
			WASHED W/CASING	
29.5–31.0		S-7	SPLIT SPOON	0-19/12"
			WASHED W/CASING	
34.5–36.0		S-8	SPLIT SPOON	2-1-1

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT)
PROJECT
HOLE NO.



Hole No. DH-4

DRILLING LOG
DIVISION NAD
INSTALLATION NAO
SHEET 1 OF 1 SHEETS
1. PROJECT KEPONE STUDY, HOPEWELL, VA.
2. LOCATION (Coordinates or Station) BAILEYS BAY N 355892.1 E 2361553.3
3. DRILLING AGENCY CUNNINGHAM DRILLING & GROUTING
4. HOLE NO. (As shown on drawing title and file number) DH-4
5. NAME OF DRILLER W. BALLARD
6. DIRECTION OF HOLE ☑ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN 46.0'
8. DEPTH DRILLED INTO ROCK 0.0'
9. TOTAL DEPTH OF HOLE 46.0'
10. SIZE AND TYPE OF BIT 2"OD SPLIT SPOON
11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL
12. MANUFACTURER'S DESIGNATION OF DRILL S&H-40C
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN DISTURBED 10 UNDISTURBED 0
14. TOTAL NUMBER CORE BOXES 0
15. ELEVATION GROUND WATER
16. DATE HOLE STARTED 11 MAY 77 COMPLETED 11 MAY 77
17. ELEVATION TOP OF HOLE BTM ELEV -2.6'
18. TOTAL CORE RECOVERY FOR BORING — %
19. SIGNATURE OF INSPECTOR R Buck

ELEVATION a	DEPTH b	CLASSIFICATION OF MATERIALS (Description) d
-2.6		(SM) fine micaceous SAND, little to some organic fines black (80% sand) lenses of (OH)
-20.1	17.5	(OH) highly organic CLAY, some silt, black (occ. lense of peat) LL = 136 PI = 73 (oven dried LL droped 56%) sand = 1% lenses of (SM)
-48.6	46	BOTTOM HOLE

	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g	
0.0–1.5		S-1	SPLIT SPOON	W/H
			WASHED W/CASING	
4.5–6.0		S-2	SPLIT SPOON	4-2-2
			WASHED W/CASING	
9.5–11.0		S-3	SPLIT SPOON	2-1-3
			WASHED W/CASING	
14.5–16.0		S-4	SPLIT SPOON	W/H
			WASHED W/CASING	
19.5–21.0		S-5	SPLIT SPOON	2-1-2
			WASHED W/CASING	
24.5–26.0		S-6	SPLIT SPOON	W/H
			WASHED W/CASING	
29.5–31.0		S-7	SPLIT SPOON	W/H
			WASHED W/CASING	
34.5–36.0		S-8	SPLIT SPOON	W/H
39.5–41.0		S-9	SPLIT SPOON	W/H-2-1
44.5–46.0		S-10	SPLIT SPOON	W/H

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT)
PROJECT
HOLE NO.

Hole No. DH-5

DRILLING LOG
DIVISION NAD
INSTALLATION NAD
SHEET 1 OF 1 SHEETS
1. PROJECT KEPONE STUDY, HOPEWELL
2. LOCATION (Coordinates or Station) GRAVELLY RUN
3. DRILLING AGENCY CUNNINGHAM DRILLING
4. HOLE NO. (As shown on drawing title and file number) DH-5
5. NAME OF DRILLER W. BALLARD
6. DIRECTION OF HOLE ☑ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN 41.0'
8. DEPTH DRILLED INTO ROCK 0
9. TOTAL DEPTH OF HOLE 41.0'
10. SIZE AND TYPE OF BIT 2"OD SPLIT SPOON
11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL
12. MANUFACTURER'S DESIGNATION OF DRILL S&H-40C
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 9, UNDISTURBED 0
14. TOTAL NUMBER CORE BOXES 0
15. ELEVATION GROUND WATER 5.0'
16. DATE HOLE: STARTED 17 MAY 77, COMPLETED 17 MAY 77
17. ELEVATION TOP OF HOLE +2.8
18. TOTAL CORE RECOVERY FOR BORING — %
19. SIGNATURE OF INSPECTOR William G. Barker

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g		
+2.8			(OH) organic CLAY some silt w/peat lenses, black		1	SPLIT SPOON	WOH	1.5
						washed w/casing		4.5
					2	SPLIT SPOON	WOH	6.0
						washed w/casing		9.5
					3	SPLIT SPOON	WOH	11.0
						washed w/casing		14.5
					4	SPLIT SPOON	WOH	16.0
-14.7	17.5		(OH) organic CLAY and fn. to med. sand trace of peat, black (44% sand)			washed w/casing		19.5
					5	SPLIT SPOON	WOH	21.0
						washed w/casing		24.5
					6	SPLIT SPOON	WOH	26.0
						washed w/casing		29.5
-26.7	29.5		(SP-SM) SAND, v. fn. to fn., tr. to little silt, lt. blue gray, NP, saturated		7	SPLIT SPOON	4-6-6	31.0
						washed w/casing		34.5
-31.7	34.5		(SP) SAND, fn. to crs. tr. silt, lt. gray NP. saturated		8	SPLIT SPOON	3-2-2	36.0
-35.7	38.5		(SP-GP) SAND, fn to crs and GRAVEL, lt gray -sat.			washed w/casing		39.5
-38.2	41.0				9	SPLIT SPOON	21-17-17	41.0
			BOTTOM HOLE					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT) PROJECT HOLE NO.

Hole No. DH-7

DRILLING LOG
DIVISION NAD
INSTALLATION NAD
SHEET 1 OF 1 SHEETS
1. PROJECT KEPONE STUDY, HOPEWELL VA.
2. LOCATION (Coordinates or Station) BAILEYS BAY N 352787.6 E 2363367.7
3. DRILLING AGENCY CUNNINGHAM DRILLING & GROUTING
4. HOLE NO. (As shown on drawing title and file number) DH-7
5. NAME OF DRILLER W. BALLARD
6. DIRECTION OF HOLE ☑ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN 41.0'
8. DEPTH DRILLED INTO ROCK 0.0'
9. TOTAL DEPTH OF HOLE 41.0'
10. SIZE AND TYPE OF BIT 2"OD SPLIT SPOON
11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL
12. MANUFACTURER'S DESIGNATION OF DRILL S&H-40C
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 9, UNDISTURBED 0
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE: STARTED 12 MAY 77, COMPLETED 12 MAY 77
17. ELEVATION TOP OF HOLE BTM ELEV -0.7
18. TOTAL CORE RECOVERY FOR BORING — %
19. SIGNATURE OF INSPECTOR R. Buck

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g		
-0.7			(OH) highly organic CLAY some silt, black.		S-1	SPLIT SPOON	W/H	0.0 1.5
						WASHED W/CASING		4.5
					S-2	SPLIT SPOON	W/H	6.0
						WASHED W/CASING		9.5
					S-3	SPLIT SPOON	W/H	11.0
			(trace of peat)			WASHED W/CASING		14.5
					S-4	SPLIT SPOON	W/H	16.0
			(lenses of peat)			WASHED W/CASING		19.5
					S-5	SPLIT SPOON	W/H	21.0
						WASHED W/CASING		24.5
					S-6	SPLIT SPOON	W/H	26.0
						WASHED W/CASING		29.5
					S-7	SPLIT SPOON	W/H	31.0
						WASHED W/CASING		34.5
					S-8	SPLIT SPOON	W/H	36.0
-38.2	37.5		(OH) & (PT) org. CLAY & PEAT, black			WASHED W/CASING		39.5
-41.7	41.0				S-9	SPLIT SPOON	W/H	41.0
			BOTTOM HOLE					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT) PROJECT HOLE NO.

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PLATE E-4

Hole No. DH-8

DRILLING LOG	DIVISION NAD	INSTALLATION NAO	SHEET 1 OF 1 SHEETS
1. PROJECT KEPONE STUDY, HOPEWELL VA.		10. SIZE AND TYPE OF BIT 2" OD SPLIT SPOON	
2. LOCATION (Coordinates or Station) BAILEYS BAY N 3582060 E 2263878.0		11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL	
3. DRILLING AGENCY CUNNINGHAM DRILLING & GROUTING		12. MANUFACTURER'S DESIGNATION OF DRILL S&H-40C	
4. HOLE NO. (As shown on drawing title and file number)	DH-8	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN	DISTURBED 9 / UNDISTURBED 0
5. NAME OF DRILLER W. BALLARD		14. TOTAL NUMBER CORE BOXES 0	
6. DIRECTION OF HOLE ☑ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.		15. ELEVATION GROUND WATER	
7. THICKNESS OF OVERBURDEN 41.0'		16. DATE HOLE	STARTED 12 MAY 77 / COMPLETED 12 MAY 77
8. DEPTH DRILLED INTO ROCK 0.0'		17. ELEVATION TOP OF HOLE BTM ELEV -3.5'	
9. TOTAL DEPTH OF HOLE 41.0'		18. TOTAL CORE RECOVERY FOR BORING — %	
		19. SIGNATURE OF INSPECTOR R. Buck	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g		
-3.5			(SM) fn. mica. SAND Some organic fines black (75% sand)		S-1	SPLIT SPOON	W/H	0.0–1.5
						WASHED W/CASING		4.5
					S-2	SPLIT SPOON	W/H	6.0
						WASHED W/CASING		9.5
					S-3	SPLIT SPOON	W/H	11.0
-16.5	13.0		(OH) highly organic CLAY, some silt trace of peat, black			WASHED W/CASING		14.5
					S-4	SPLIT SPOON	W/H	16.0
						WASHED W/CASING		19.5
					S-5	SPLIT SPOON	W/H	21.0
						WASHED W/CASING		24.5
					S-6	SPLIT SPOON	W/H	26.0
-31.5	28.0		(OH) & (PT) highly organic CLAY and PEAT, black			WASHED W/CASING		29.5
					S-7	SPLIT SPOON	WH-3-2	31.0
						WASHED W/CASING		34.5
-33.5	35.0		(SM) fn. to med. SAND little org. fines, tr. peat, gray (82% sand)		S-8	SPLIT SPOON	4-5-6	36.0
-41.5	38.0		(OH) & (PT) organic CLAY & PEAT			WASHED W/CASING		39.5
					S-9	SPLIT SPOON	WH-1-1	41.0
-43.5	41.0		BOTTOM HOLE					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT) PROJECT HOLE NO.

Hole No. DH-9

DRILLING LOG	DIVISION NAD	INSTALLATION NAO	SHEET 1 OF 1 SHEETS
1. PROJECT KEPONE STUDY		10. SIZE AND TYPE OF BIT 2" OD SPLIT SPOON	
2. LOCATION (Coordinates or Station) HOPEWELL VA.		11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL	
3. DRILLING AGENCY CUNNINGHAM DRILLING & GROUTING		12. MANUFACTURER'S DESIGNATION OF DRILL S&H-40C	
4. HOLE NO. (As shown on drawing title and file number)	DH-9	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN	DISTURBED 6 / UNDISTURBED 0
5. NAME OF DRILLER W. BALLARD		14. TOTAL NUMBER CORE BOXES 0	
6. DIRECTION OF HOLE ☑ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.		15. ELEVATION GROUND WATER	
7. THICKNESS OF OVERBURDEN 30.0'		16. DATE HOLE	STARTED 12 MAY 77 / COMPLETED 12 MAY 77
8. DEPTH DRILLED INTO ROCK 0.0'		17. ELEVATION TOP OF HOLE -3.8	
9. TOTAL DEPTH OF HOLE 30.0'		18. TOTAL CORE RECOVERY FOR BORING — %	
		19. SIGNATURE OF INSPECTOR R. Buck	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g		
			(OL)					0.0
-4.3	0.5		(SP-SM) fn. to med. SAND, dk. gray		S-1	SPLIT SPOON	W/H	1.5
-6.8	3.0		(OL) organic SILT & clay, some fine sand, dk. gray			WASHED W/CASING		9.5
					S-2	SPLIT SPOON	W/H	11.0
-16.8	13.0		(PT) PEAT & wood w/org. clay & silt			WASHED W/CASING		14.5
					S-3	SPLIT SPOON	W/H	16.0
-21.8	18.0		(OH) & (PT) organic CLAY & PEAT			WASHED W/CASING		19.5
					S-4	SPLIT SPOON	W/H	21.0
-26.8	23.0		(SP-SM) fn. SAND trace of org. fines & peat, dk. gray. (91% sand)			WASHED W/CASING		24.5
					S-5	SPLIT SPOON	3-4-5	26.0
					S-6	Sam. from casing		
-33.8	30.0							

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT) PROJECT HOLE NO.

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PLATE E-5

Hole No. DH-10

DRILLING LOG	DIVISION NAD	INSTALLATION NAO	SHEET 1 OF 1 SHEETS
1. PROJECT KEPONE STUDY		10. SIZE AND TYPE OF BIT 2"OD SPLIT SPOON	
2. LOCATION (Coordinates or Station) HOPEWELL VA.		11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL	
3. DRILLING AGENCY CUNNINGHAM DRILLING & GROUTING		12. MANUFACTURER'S DESIGNATION OF DRILL S&H-40C	
4. HOLE NO. (As shown on drawing title and file number)	DH-10	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED 6 / UNDISTURBED 0
5. NAME OF DRILLER W. BALLARD		14. TOTAL NUMBER CORE BOXES 0	
6. DIRECTION OF HOLE ☑ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.		15. ELEVATION GROUND WATER	
7. THICKNESS OF OVERBURDEN 31.0'		16. DATE HOLE	STARTED 12 MAY 77 / COMPLETED 12 MAY 77
8. DEPTH DRILLED INTO ROCK 0.0'		17. ELEVATION TOP OF HOLE -2.6	
9. TOTAL DEPTH OF HOLE 31.0'		18. TOTAL CORE RECOVERY FOR BORING %	
		19. SIGNATURE OF INSPECTOR P Buck	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g		
-2.6			(SM-SP) fn. to med. SAND little org. fines, dk gray		S-1	SPLIT SPOON	W/H	0 1.5
-4.6	2.0		(OL) organic SILT and clay, some fine sand (25%), dk. gray. LL = 46 PI = 25 (oven dried LL droped 33%)		S-2	SPLIT SPOON	W/H	4.5 6.0
					S-3	SPLIT SPOON	W/H	9.5 11.0
					S-4	SPLIT SPOON	W/H	14.5 16.0
-20.6	18.0		(SM) fine SAND, some organic fines, trace of peat, gray (80% sand)		S-5	SPLIT SPOON	3-4-3	19.5 21.0
-26.6	24.0				N/R	SPLIT SPOON	FIRM	24.5 26.0
			(SP) fn. SAND, gray. (Sand entering casing)		S-6*	SPLIT SPOON	FIRM	29.5 31.0
-31.6	31.0		BOTTOM HOLE					
			* Sam. taken from spoon pumped in casing.					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT) | PROJECT | HOLE NO.

Hole No. DH-11

DRILLING LOG	DIVISION NAD	INSTALLATION NAD	SHEET 1 OF 1 SHEETS
1. PROJECT KEPONE STUDY		10. SIZE AND TYPE OF BIT 2"OD SPLIT SPOON	
2. LOCATION (Coordinates or Station) UPPER BAILEY CREEK		11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL	
3. DRILLING AGENCY CUNNINGHAM		12. MANUFACTURER'S DESIGNATION OF DRILL S&H-40C	
4. HOLE NO. (As shown on drawing title and file number)	DH-11	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED 8 / UNDISTURBED 0
5. NAME OF DRILLER W. BALLARD		14. TOTAL NUMBER CORE BOXES 8	
6. DIRECTION OF HOLE ☑ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.		15. ELEVATION GROUND WATER	
7. THICKNESS OF OVERBURDEN 41.0'		16. DATE HOLE	STARTED 17 May 77 / COMPLETED 18 May 77
8. DEPTH DRILLED INTO ROCK 0		17. ELEVATION TOP OF HOLE +7.8	
9. TOTAL DEPTH OF HOLE 41.0'		18. TOTAL CORE RECOVERY FOR BORING — %	
		19. SIGNATURE OF INSPECTOR William J Barlow	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g		
+6.8	1.0		(OH) ORGANIC silty CLAY		1	SPLIT SPOON	PUSH	1.5
+5.8	2.0		(CH) CLAY, hi plast, v. moist			washed w/casing		
			(SM-ML) SAND, v. fn and SILT, dk. gray, slt. plast., v. moist		2	SPLIT SPOON	2-1-1	3.5 5.0
+1.8	6.0		(SP-SC) SAND, fn-crs tr to some hi plast. clay in lenses, tr. gravel, lt. blue gray saturated -running sands under artesian head			washed w/casing		
					3	SPLIT SPOON	7-10-13	9.5 11.0
						washed w/casing		
					4	SPLIT SPOON	13-19-15	14.5 16.0
-8.2	16.0		(SP-GP) SAND, fn to crs and Gravel, tr. silt & clay, lt. gray, saturated, dense Cored some cobbles w/BX barrel Material may have greater amount of fines washed out by coring and advancing casing			washed w/casing		
					5	Split Spoon	30/.4	19.5 21.0
						BX core barrel used to advance casing to coarse sands & gravels also required washing w/rods thru casing to advance		
					6	SPLIT SPOON	42-40-37	29.5 31.0
						washed w/casing		
-27.2	35.0		(SM-ML) SAND, v. fn. and SILT, lt. green gray, slt. plast, moist glauconitic sands		7	SPLIT SPOON	22-21-26	34.5 36.0
						washed w/casing		
					8	SPLIT SPOON	31-29-22	39.5 41.0
-33.2	41.0		BOTTOM HOLE					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT) | PROJECT | HOLE NO.

PLATE E-6

Hole No. DH-12

DRILLING LOG	DIVISION NAD	INSTALLATION NAD	SHEET 1 OF 1 SHEETS
1. PROJECT KEPONE STUDY		10. SIZE AND TYPE OF BIT 2" OD SPLIT SPOON	
2. LOCATION (Coordinates or Station) UPPER BAILEY CREEK		11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL	
3. DRILLING AGENCY CUNNINGHAM		12. MANUFACTURER'S DESIGNATION OF DRILL S&H - 40C	
4. HOLE NO. (As shown on drawing title and file number)	DH-12	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN	DISTURBED 4 / UNDISTURBED 0
5. NAME OF DRILLER W. BALLARD		14. TOTAL NUMBER CORE BOXES 0	
6. DIRECTION OF HOLE ☑ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.		15. ELEVATION GROUND WATER	1.5 @ COMP.
7. THICKNESS OF OVERBURDEN	16.0'	16. DATE HOLE	STARTED 17 MAY 77 / COMPLETED 17 MAY 77
8. DEPTH DRILLED INTO ROCK	0	17. ELEVATION TOP OF HOLE	+6.7
9. TOTAL DEPTH OF HOLE	16.0'	18. TOTAL CORE RECOVERY FOR BORING	— %
		19. SIGNATURE OF INSPECTOR	William J. Baker

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g		
+5.7	1.0		Bn Sandy topsoil		1	SPLITSPOON	2-2-2	1.5
+4.7	2.0		(SM)SAND, vm-fn, silty			washed w/casing		
			(SC-CH)SAND, fn. to medi & CLAY, hi plast white to lt. blue gray very moist		2	SPLITSPOON	3-3-3	4.5 6.0
						washed w/casing		
					3	SPLITSPOON	4-7-8	9.5 11.0
						washed w/casing		
-8.8	15.5		(GP) Grav & Sand		4	SPLIT SPOON	9-9-11	14.5 16.0
-9.3	16.0		BOTTOM HOLE					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT)

PROJECT

HOLE NO.

460<

Hole No. DH-13

DRILLING LOG	DIVISION NAD	INSTALLATION NAO	SHEET 1 OF 2 SHEETS
1. PROJECT KEPONE STUDY		10. SIZE AND TYPE OF BIT 2" OD SPLIT SPOON	
2. LOCATION (Coordinates or Station) HOPEWELL VA.		11. DATUM FOR ELEVATION SHOWN (TBM or MSL) MSL	
3. DRILLING AGENCY CUNNINGHAM DRILLING & GROUTING		12. MANUFACTURER'S DESIGNATION OF DRILL S&H-40C	
4. HOLE NO. (As shown on drawing title and file number) DH-13		13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN	DISTURBED 12 / UNDISTURBED 0
5. NAME OF DRILLER W. BALLARD		14. TOTAL NUMBER CORE BOXES 0	
6. DIRECTION OF HOLE ☑ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.		15. ELEVATION GROUND WATER	
7. THICKNESS OF OVERBURDEN 54.5'		16. DATE HOLE	STARTED 13MAY77 / COMPLETED 13MAY77
8. DEPTH DRILLED INTO ROCK 0.0'		17. ELEVATION TOP OF HOLE -3.5	
9. TOTAL DEPTH OF HOLE 54.5		18. TOTAL CORE RECOVERY FOR BORING — %	
		19. SIGNATURE OF INSPECTOR R Buck	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g		
-3.5			(SM) fn. to med. SAND little fines, org., black		S-1	SPLIT SPOON	W/H	0.0 1.5
-6.0	2.5		(OH) highly organic CLAY, some silt, tr. fine sand (9%), black. LL = 90 PI = 40 (oven dried LL droped 52%)			WASHED W/CASING		
					S-2	SPLIT SPOON	W/H	4.5 6.0
						WASHED W/CASING		
					S-3	SPLIT SPOON	W/H	9.5 11.0
						WASHED W/CASING		
					S-4	SPLIT SPOON	W/H	14.5 16.0
-21.0	17.5		(OH) highly organic CLAY, some silt, some fine sand (24%), black. LL: 57 PI = 23 (droped 47%)			WASHED W/CASING		
					S-5	SPLIT SPOON	W/H	19.5 21.0
						WASHED W/CASING		
					S-6	SPLIT SPOON	W/H	24.5 26.0
-31.0	27.5		(SM) fine micaceous SAND and organic fines, dk. gray			WASHED W/CASING		
					S-7	SPLIT SPOON	WH-3-2	29.5 31.0
			(53% sand)			WASHED W/CASING		
					S-8	SPLIT SPOON	1-2-1	34.5 36.0
						WASHED W/CASING		
					S-9	SPLIT SPOON	2-3-3	39.5 41.0
			(59% sand)			WASHED W/CASING		
					S-10	SPLIT SPOON	-1 blow	44.5 46.0
			occ. lenses of (OH) & (SP)			WASHED W/CASING		
-53.5								49.5 50.0

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT) PROJECT HOLE NO.

Hole No. DH-13

DRILLING LOG	DIVISION	INSTALLATION	SHEET 2 OF 2 SHEETS
1. PROJECT		10. SIZE AND TYPE OF BIT	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
4. HOLE NO. (As shown on drawing title and file number)		13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN	DISTURBED / UNDISTURBED
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.		15. ELEVATION GROUND WATER	
7. THICKNESS OF OVERBURDEN		16. DATE HOLE	STARTED / COMPLETED
8. DEPTH DRILLED INTO ROCK		17. ELEVATION TOP OF HOLE	
9. TOTAL DEPTH OF HOLE		18. TOTAL CORE RECOVERY FOR BORING %	
		19. SIGNATURE OF INSPECTOR	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g		
					S-11	SPLIT SPOON	4-5-10	50 51.0
-55.5	52.0		(SM-SP) fn. to crse. SAND w/ decomposed wood			WASHED W/CASING		
-58.0	54.5				12	sam. from casing		

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT) PROJECT HOLE NO.

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PLATE E-8